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W Birch

Dr. BOERHAAVE'S
Academical Lectures
ON THE
Theory of PHYSIC.
BEING
A Genuine Tranſlation of his
INSTITUTES
AND
Explanatory COMMENT,

Collated and adjuſted to each other, as they were dictated to his STUDENTS at the Univerſity of *Leyden*.

VOL. III.

Containing the Structure and Action of the Spleen, Omentum, Liver, Kidneys, Bladder, Muſcles and Skin; with the Nature of Sweat, Perſpiration and Nutrition.

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The Action of the SPLEEN.

§. 312. THE Seat of the Spleen, with its Vicinity to the cœliac Artery, and its Office with reſpect to the Liver, as alſo the particular Courſe of its Humours, requires of us in the next place to treat firſt of that Viſcus.

§. 313. It is ſituated in the left *Hypochondrium*[1], hangs *pendulous*[2] from the Diaphragm, and adhering to the left Kidney and to the Omentum, it is by this laſt in a manner connected to the Stomach; whence it eaſily permits itſelf to be variouſly *preſſed*[3], and agitated upwards and downwards, by the Motion of the Diaphragm and abdominal Muſcles, (§. 86.)

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[1] This is the natural Seat of the Spleen; tho' there are three or four Inſtances upon Record, in which the Viſcera being reverſed, the Spleen has been found ſeated in the right Hypochondrium.

[2] Not fix'd, but at liberty on all Sides; ſo that it may be variouſly agitated and preſſed up and down with the Diaphragm, more eſpecially in Brutes.

[3] The whole Cavity or Sack of the Abdomen is extremely full, and is contracted againſt all the Viſcera with a conſiderable Force by the Muſcles

placed round: but this force is alternate and unequable, and therefore the abdominal Viſcera ſuffer an alternate and unequal Preſſure. In Inſpiration all thoſe Viſcera are preſſed downward with a conſiderable Force by the incumbent Diaphragm; but in Expiration, on the contrary, they are preſſed upward and backward with no leſs Force by the Muſcles of the Abdomen, which thruſt the Peritonæum towards the back. But how great the Force is with which the abdominal Muſcles operate, *Sennertus* demonſtrates by inſtancing a Student, who was wounded through the Diaphragm by Puncture with a Sword: for though the Wound was but ſmall, yet the Stomach was obliged to aſcend into the Thorax through the dilated Wound, from the perpetual Contraction of the abdominal Muſcles, ſo as to kill the Patient after the moſt ſevere Pains. But beſides the Force of the Muſcles here conſider'd, the Stomach alſo preſſes upon the Spleen when diſtended with Aliments, and by that means thruſts it againſt the lateral Arch of the Peritonæum. Hence the Spleen appears altogether like a Spunge full of Blood, confined in a ſtrong Membrane, which receives the ſtrong Preſſures from the ambient Parts by which the venal Blood is preſſed out of the Spleen towards the Liver. For that the Paſſage of the venal Blood of the Spleen towards the Liver is ſlow and difficult, Men of Letters, who lead ſedentary Lives, experience to their Detriment. For when theſe retire to reſt in Solitude, that the Mind may perform its Operations more diſtinctly, if they neglect to promote the Courſe of the Blood by proper Exerciſe of Body, it becomes accumulated in the Veins of the Spleen, ſtagnates and thickens ſo as to prove a Source to an infinite Number of other Diſeaſes; from whence Weakneſs,

neſs, Inflations, and all the various Symptoms which appear under the Denomination of hypochondriacal Diſorders. In ſhort, the Spleen ſtands ſo much in need of this alternate Preſſure to forward the Courſe of its Blood, that without it, it muſt ſtagnate, and be ſcarce capable of performing its Circulation.

§. 314. It receives the pure arterial Blood ſoon after it has been expelled from the Heart, by the *firſt* [1] conſiderable Artery which ariſes beneath the Diaphragm, namely, the cœliac Artery: for whilſt the firſt Branch of this Artery ſends out this to the Spleen, the *third* [2] Branch often ſends out three others to it; or ſometimes this Artery ariſes from the Aorta in ſuch a manner, as to ſend its Branches to the Liver, Pancreas, Duodenum, and Stomach, which receive their Arteries from the ſame Trunk with the Spleen; whence it appears that the Blood diſtributed to all thoſe Parts is of the ſame Nature.

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[1] All the Blood of the Spleen is derived from the cœliac Artery, which is the very firſt Branch that ariſes from the Aorta below the Diaphragm. The ſame Blood was but the moment before in the Heart itſelf, ſince when no kind of Humour was ſeparated. It is true, the Blood of the deſcending Aorta is heavier than that which aſcends, but yet it does not deſerve the Name of fæculent Blood, or *atrabilis*.

[2] This is not conſtantly obſerved in Nature; and ſometimes the Branch from the cœliac Trunk is ſingle; and ſometimes there are two or three Branches, as in the emulgent Arteries.

§. 315. Theſe Arteries of the Spleen which are large, and a great deal *bigger* [1] than thoſe of the Liver, having enter'd into its Body, are immediately diſtributed throughout the whole Maſs of the Spleen, divided into an infinite Number of *ſmall Branches* [2], whoſe Extremities are collected and ſpent in Bunches of very minute Ducts, which have in ſome meaſure the Appearance of ſmall *Glands* [3]; and in this manner do the ſplenic Arteries vaniſh in every Part about the Extremities of the correſponding Veins.

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[1] The ſplenic Arteries are at leaſt ſix times larger than the hepatic; but the Weight of the Spleen is ſcarce a fourth Part to that of the Liver: and therefore, in a given time, twenty-four times as much Blood will paſs through the Arteries of the Spleen, as through thoſe of the Liver. And the Quantity of this Blood is ſtill larger, as the Spleen conſiſts entirely of Veſſels without any Fat or Muſcle in its Compoſition; from whence it ſeems to be manifeſt, that the Liver receives its arterial Blood for its own proper Uſe, but that the Spleen does not receive all that Blood for its ſelf, but for the common Uſe of ſome other Parts. But ſo ſoon as the ſplenic Artery has enter'd the Subſtance of that Viſcus, it depoſits its muſcular Coat, as we obſerved of the carotid Artery; which muſcular Coat ſerves to compoſe the proper Tunic itſelf of the Spleen, which is white, compact, and thick. And betwixt this Coat and the outermoſt and common Tunick derived from the Peritonæum, there are diſtributed ſmall Veſſels and lymphatic Ducts. But the Artery divides itſelf into

to two Claſſes, one of which ſerves for the Nutrition of the Spleen, having lymphatic Veins formed for the venal Syſtem: and the other Claſs, which conveys the Blood for ſome common Uſe, diſappearing in very ſmall Branches; many of which are formed into ſmall Bundles or Bunches, ſo as to reſemble a round or obtuſe Body. From hence *Ruyſch* confeſſes, that he imagined the Spleen to have the ſame glandular Fabric with many of the other Glands.

[2] The Artery is diſtributed in large Branches through the whole Spleen, in every Part of which they ſeem to terminate in little Heaps, as far as our Senſes are capable of diſtinguiſhing: for if the Spleen be examined after it has been dried of itſelf, you can diſtinguiſh nothing in the Extremities of the Veſſels; but if it is firſt filled by the *Ruyſchian* Art of injecting, then the whole Maſs of it ſeems to be converted into the ceraceous Injection.

[3] *Ruyſch* formerly confeſſed in more Places than one of his Writings, that he diſcovered ſmall Glands in the Spleen; a while afterwards he aſſerted that he could diſcern ſmall Bodies, but of an unknown Fabric; and again, after this he teſtifies that he can find nothing elſe but Veſſels; and this notwithſtanding he was a Man of great Veracity, averſe to Reaſoning or Hypotheſis, but a ſimple Hiſtorian or Relator of Facts.

§. 316. The *comparative* [1] Anatomy of this Viſcus, as it appears in Men, Oxen, Sheep, Moles, *Hedgehogs* [2]; the morbid Diſpoſition of it in dead Bodies, in which the Spleen is beſet with *petrified* [3] Tubercles, and the Appearance obſervable in a *macerated* [4] Spleen;

all render it probable that the ſmall Arteries (315.) degenerate into a glandular Fabric (242 to 254.)

[1] It was cuſtomary with *Malpighi* to trace thoſe Viſcera through all the Species of Animals and Inſects, whoſe Fabric he could not any way diſcover in the human Body; in order that he might diſcover in one Species what was concealed in the other; and he found that all Animals had both a Liver and Spleen, the Liver being larger in proportion as the Animal is colder.

[2] In this Animal the Spleen, as well as the other Viſcera, is compoſed of many diſtinct Lobes like Glands.

[3] Not only *Malpighi*, but alſo many other Anatomiſts have obſerved human Spleens in chronical Diſeaſes to be filled internally with round petrified Bodies, or elſe filled with ſome hard Matter, which ſeems to be ſituated without the Limits of the Arteries or Veins. There is therefore in the Spleen certain Cavities into which that morbid Matter is depoſited: for it does not ſeem probable that thoſe Cavities were made in the Diſeaſe, but that they were rather ſo ſmall as to be inviſible in their natural State, but by Diſtention with impacted Humours, they become at length conſpicuous to the naked Eye.

[4] The Spleen being macerated in warm Water, drinks in that Water by its lymphatic Veſſels, which are therefore eaſily demonſtrated by this ſimple Contrivance; and if it be afterwards freed from its Integuments, its natural Fabric will appear very much like the glutinous Silk which has been lately ſpun by the Worm, and there will appear a great Number of little Bladders full of Water within its Subſtance. But theſe Bladders differ

from Glands, inaſmuch as they are deſtitute of excretory Ducts, at leaſt any that could be diſcover'd by the greateſt Induſtry of *Malpighi*. But it is ſufficient for our Purpoſe, that we find an intermediate or thin Subſtance betwixt the Arteries and Veins of the Spleen, either of a glandular or veſicular Fabrick, the Appearance of which is not denied even by *Ruyſch* himſelf.

§. 317. But as an artificial Injection of the Veſſels in this Viſcus demonſtrates a direct or ready *Paſſage* [1] from the Arteries into the Veins, therefore it would ſeem that all the Extremities of the ſplenic Arteries do not terminate in the ſame manner, but that they conſiderably *differ* [2] in their Extremities from each other; which Difference however has not yet been diſtinctly exhibited to the Eye by any *Artifice* [3] hitherto known, chiefly becauſe of the great Tenderneſs or Friability of this ſoft Viſcus.

[1] For Water or even ceraceous Matter being injected by the ſplenic Artery, very eaſily returns through the ſplenic Veins, and the reverſe; as is evident from the Experiments of *Swammerdam* and *Ruyſch*.

[2] So that ſome of the Arteries return their Blood immediately into the Veins, while others pour it firſt into an intermediate Cavity or Cell; namely, into the Veſſels or ſmall glandular Corpuſcles before obſerved.

[3] For even *Ruyſch* himſelf, nor any other Anatomiſt, could ever entirely demonſtrate the Fabric of the Spleen. For even the very Injection itſelf, from the Softneſs or Perviouſneſs of the Viſcus,

confounds the Eyes and Examination of the Anatomiſt; inſomuch that a Spleen which has been the moſt happily injected, being cut through the Middle, appears as it were one continued Maſs of Wax, ſo that one cannot diſtinguiſh the different Kinds of Veſſels; and if the external Coats are taken off, the ſoft Viſcus diſſolves or unravels itſelf, ſo as to fluctuate almoſt in the manner of the Brain which has been macerated; by which means every thing is confuſed, in ſuch a manner that I have not yet been able to determine my Judgment with Certainty concerning the Fabric of the Spleen, which is more difficult to ſearch well into than any other Viſcus. If you macerate a Spleen uninjected in Water for ſome time, as was formerly done by *Vanhorne*, but latterly by *Ruyſch*, all the fleſhy Subſtance of the Spleen will then be gradually diſſolved barely by Putrefaction, and a gentle Concuſſion. If Mercury is injected into the Spleen after the manner of *Nucke*, it then turns into a hollow Bag full of Quickſilver. If again you inflate Wind by the Artery into a Spleen whoſe Blood has been waſhed out, and its Vein tied, after drying and cutting it open, it appears to be nothing elſe but Fibres.

§. 318. It is evident at leaſt that the *Structure* [1] of this Viſcus is much the ſame with that obſerved in all other Parts, wherein a Secretion is performed, and therefore it would ſeem that the ſame Action muſt be alſo performed here: but yet there is no common excretory *Duct* [2] coming from the Spleen; and the *Lymphatics* [3] which are found in it, run only betwixt the two Membranes in the Spleen, and alſo in ſome Places at a Diſtance from the ſplenic Artery, being fewer in Man than in other Animals; nor do they enter into the inner Subſtance of the Spleen, nor ariſe from the Extremities of theſe Veſſels, which ſerve for the Nutrition of the Body of the Spleen.

[1] Namely, there is here an Artery importing Blood, which is alſo accompanied with an exporting Vein; and there is alſo a third, ſomething which is neither Artery nor Vein, but which receives the Blood and retains it for ſome time. Hence therefore it may not be unreaſonable to conclude, that ſome kind of Secretion is made in the Spleen; ſince the ſame Fabric being given, as the ſame Cauſe, ought neceſſarily to produce the ſame Effect.

[2] From the internal Side of the Spleen, no Veſſel comes out beſides the Vein; but a Vein is no excretory Duct, ſince it returns nothing but the ſuperfluous Blood towards the Heart; and in every ſecretory Organ there is a diſtinct Veſſel beſides a Vein, carrying a diſtinct Humour, prepared by the Organ, for the Uſe of its ſelf and of the whole Body. Thus in the Kidney, beſides the renal Arteries and Veins which correſpond to thoſe Arteries, there is an excretory Duct called the Ureter. In the Pancreas, beſides the Arteries ramified from the Cœliac, and the Veins correſponding to them, there is alſo a ſalival Duct, which carries a thin Liquor to the inteſtinum Duodenum; and this is the common Fabric of the Glands and Viſcera, from which the Spleen only is excepted, as having no peculiar third kind of Veſſel.

[3] It is no difficult Matter to refute the Theory of *Gliſſon*, who imagined the Spleen to be formed to draw a large Quantity of Lymph from the Blood. For the Lymph flows back from every Part of the

Body, whether any Secretions be made in it or not. Thus there are numerous Lymphatics in the Liver and Kidneys, which are ſecretory Organs, and alſo in the Lungs which is no ſecretory Organ; which Veſſels have been demonſtrated and repreſented by *Nucke*, whoſe Preparations of the lymphatic Veins taken out of the Body and artfully preſerved, I have frequently viewed with much Pleaſute. The Office of the lymphatic Veſſels is common to the whole Body, and does not relate to the Fabric of any particular Part. It is indeed true, that every leaſt Particle ſtands in need of being nouriſhed, but nothing can be brought for Nutrition except through the ſanguiferous Arteries, (§. 261.) which are the largeſt Series of the ſmaller Veſſels; (§. 226.) and therefore there is a Neceſſity for pellucid Arteries which exclude the red Blood by their Smalneſs, in order to convey Serum, Lymph, and more thin Juices for the Nutrition of thoſe Parts which do not admit the red Blood. (§. 245, 261.) But Arteries have always their correſponding Veins, to return thoſe Juices again to the Heart, which have not been conſumed in Nutrition; and theſe are the Veins which we call lymphatic Veſſels; which being every where ſeated, the particular Uſe of the Spleen cannot be therefore reſtrained to the lymphatic Veſſels.

§. 319. Since therefore comparative Anatomy teaches us that the ſame Structure of this Viſcus is obſervable in *moſt* [1] Brutes; therefore the ſame Fabric may alſo take Place in the human Spleen, though it cannot be there ſo eaſily demonſtrated to the Eye. But ſuch however is the Structure of it in Calves, *&c.* as follows. The very large ſplenic Vein having enter'd ter'd that Viſcus and diſtributed its Branches every way throughout its Subſtance, appears to have ſmall Foramina or Perforations in the Sides of its Branches, ſufficiently conſpicuous to the Eye as far as it can trace them, until the Vein is ſo minutely ramified as almoſt to vaniſh about the Extremities of the ſmal Arteries, where the Nerve is alſo ſpent at the ſame time; from hence it follows, that the ſplenic Vein may be filled as well by theſe large lateral Foramina, as by the Extremities of thoſe Veſſels which are continued to the Arteries or Corpuſcles like Glands; (§. 315.) and that therefore the ultimate Mouths of the ſmall Veins may receive and return the Blood from the glandular Fabric, while theſe larger Orifices which open in the Cavities of the Veins, receive thoſe Humours which may be evacuated into them from the adjacent Receptacles, while the Compages of the Spleen itſelf is ſtrengthened by ſtrong tranſverſe Fibres.

[1] If Nature appears conſtantly to uſe the ſame Fabric of a part in twenty different Animals, it is probable ſhe will not alter her Mechaniſm in the next Animal of the ſame Genus, even though the Fabric is ſomewhat more concealed from us; nor is there any Inſtance of a Viſcus, which is of a different Fabric in Man from that in other Animals. I have myſelf diligently examined the Fabric of the Spleen in above twenty different Animals, and always found it as deſcribed by *Malpighi*: therefore, there does not ſeem to be any Neceſſity for ſearching after a different Structure in the human Spleen, even though it appears more friable than the ſame Viſcus in Brutes.

§. 320. If Air be inflated through the *ſplenic Artery* [1] into the Subſtance of that Viſcus which has had its Blood waſhed out, and the correſponding Vein afterwards directly tied, that Air will be diſperſed throughout the whole Subſtance of it, which is pervious; and if then the Artery be alſo tied, and the Spleen cut in two after it has been dried in the Air, there will not only appear many Arteries, Veins and Nerves, but alſo many diſtinct, empty and diſtended Cells, of various Forms and Capacities, compoſed of upright Membranes; which Cells have a manifeſt Communication with each other, and alſo with thoſe larger Foramina, or lateral Perforations in the Cavities of the Veins.

[1] This Experiment is indeed troubleſome, but it always anſwers the Expectation. Take the Spleen of a ſound Calf, to which adapt a Siphon, and inject warm Water by the Artery, which will very ſpeedily return by the Vein; continue the Injection 'till the Water returns as clear by the Vein, as it enter'd by the Artery. But even then it is not ſufficiently cleanſed; but Water is to be ſeveral times injected, and gently preſſed out by the Hands: and when at length the Spleen appears pale and bloodleſs, the Vein is then to be tied, and Wind blowed in by the Artery. Thus the whole Spleen will ſwell; and after tying the Artery in like manner, ſuſpend it in the Air until it is dry. If then the external Membrane be peeled off, by holding it over the Vapours of hot Water, the internal Fabric of this Viſcus will appear, namely, a Congeries of Arteries, Veins, and Cells;

which laſt are ſtrengthen'd by Fibres of their own, and receive the extremities of the Veſſels on all Sides into their Cavities. Thus the Termination of one Claſs of Veins will not be conſpicuous, where they are united with the Arteries; but the others will appear evident enough, continued from the large Cells, into which the Foramina of the ſplenic Vein open. Thus you ſee in one Preparation, a twofold Termination of the Veins is demonſtrated; one continuous with the Arteries, as when the Water injected by the Artery flowed out by the Veins in the recent Spleen; the other opening into the Cells, which are eaſily conſpicuous in the dried Spleen. It muſt be confeſſed that this Preparation does not ſucceed in the human Spleen, by reaſon of its great Tenderneſs, which will not allow of it to be thus treated. But yet in the Spleen of the gigantick Girl, (ſeven Foot high) which was injected by *Ruyſch*, there appeared ſomething like this Fabrick of the Calf's Spleen, namely, certain Corpuſcles which might be eſteemed Cells.

§. 321. The Sides of the Membranes which compoſe the forementioned Cells are ſpread with exceeding ſmall Arteries, but there are alſo ſmall, white, and ſoft Corpuſcles, of an oval Figure, diſpoſed in numerous Cluſters within the Membranes compoſing theſe Cells, and which ſeem to have all the ſenſible Appearances of *Glands*[1]; and yet *Ruyſch* takes them to be the ultimate and pulpy Extremities of the ſmall Arteries, complicated together in Bunches after a particular Manner.

[1] *Ruyſch*, who firſt admitted Glands in the Spleen, afterwards changed his Opinion, and would not allow there were any. The glandular Corpuſcles in the Spleen ſeem to become pellucid, by waſhing them with warm Water; and they then diſappear; but become viſible again, after being injected or filled with ſome coloured Fluid.

§. 322. In the mean time there are many large and diſtinct *Nerves* [1], continued into the Spleen only, and diſtributed throughout every Part of it, when at the ſame time there ſeems to be ſcarce any ſenſible Motion, nor any ſharp Senſation performed in it; nor are any ſuch Qualities obſerved to be neceſſary in it: from whence therefore it ſeems very probable, that even the Nerves convey their moſt ſubtle *Humour* [2] to this Viſcus, into which it is diſtilled and mixed with the other venal Juices there found.

[1] Nerves ſo large and numerous, that *Gliſſon* takes the Spleen to be a Ciſtern for the Spirits; from the Reſervoir of which ſome Addition is made to the nervous Fluid, and this he takes to be the Reaſon why there are ſo many Nerves entering the Spleen. But the ſame Phyſician, being a Man of Candor, even condemned his own Hypotheſis after more mature Conſideration, when he perceived that it was not agreeable to the Courſe of Nature to ſuppoſe two Origins of the Nerves, one from the Brain, and the other from the Spleen.

[2] The Spleen is never in Pain to any great degree; and even in high Inflammations and large Tumors, in which a Schirrhus is formed, the Pain is felt only in its Membranes. There are many extraordinary Inſtances of People who have been

opened after Death, and their Spleen found enlarged to a very great degree, and yet they never made any great Complaints of feeling any Uneaſineſs in the left Hypochondrium. But theſe Nerves are here as little required for Nutrition, as for Senſation; we muſt therefore ſuppoſe the Nerves to conduce to ſome Change in the Blood, which it may render more fluid in the Spleen by mixing itſelf therein. In ſhort, the Spleen ſeems to be a ſort of Lungs, in whoſe Cells the extravaſated Blood is alternately ſhook and divided by the continual Action of the Diaphragm in Reſpiration. But as the Blood elaborated in the Lungs is conveyed into the Heart, ſo the Blood of the Spleen is conveyed into the Liver; and therefore the Spleen is to the Liver, what the Lungs are to the whole Body.

§. 323. From hence therefore the principal Action of the Spleen ſeems to be, to receive, prepare, ſeparate, and tranſmit the arterial Blood pure and *diluted* 1 with Lymph, paſſing through its ſmall glandular *Corpuſcles* 2 (§. 316.) by their proper Emiſſaries into each of the Cells (§. 320, 321.); and partly perhaps to tranſmit ſome of the ſame Blood into the ſplenic *Veins* 3. 2. To convey the Blood remaining after this Action to the ſmall Veins, and from thence into the common ſplenic Vein. 3. For one Parcel of the ſmall *Arteries* 4, namely, thoſe which inveſt the Cells (§. 321.), poſſible to *pour in* 5 the Blood, attenuated by the arterial Fabric, repleniſh'd with Lymph, into the ample Cavities of thoſe Cells, as is obſerved to happen in the cellular

Subſtance of the Penis of the Male. 4. (As we believe) likewiſe to depoſit, receive, and *mix* 6 a large Quantity of nervous Juice with the ſame Blood, to be conſtantly ſent thither again. 5. To receive all theſe Humours thus prepared, confuſedly mixed and ſtagnating for a Moment, ſo as to attenuate, intimately mix and preſs them together, almoſt in the *ſame Manner* 7 as the Blood in the Lungs; and this by the Force of the arterial Blood, the Impetus of the nervous Juice, the proper Contraction of its two membranous Coats and Vagina, the Contraction of its numerous Fibres, with the Agitation of the Diaphragm, and the Preſſure received from the adjacent Muſcles, Veſſels, and Viſcera of the Abdomen.

[1] It was mixed but a little before in the Heart with all the Humours of a more fluid Nature; nor does it part with any thing by the way, to form any kind of Secretion.

[2] Which even *Ruyſch* himſelf has admitted under a Name a little different, and leſs known, namely, that of Corpuſcles. But their Office ſeems to be that of all other Glands, namely, the Secretion of ſome diluent Juice, which is poured into the Veins; as may appear from the patulent Mouths of the Glands, which correſpond to the Veins.

[3] In this reſpect the Spleen differs from other Viſcera, in that it ſecerns nothing, and works by its whole Fabric, only to expedite or haſten the Courſe of the Blood from the Arteries into the

Veins. The ſame thing does alſo the Lungs, but without the Aſſiſtance of Glands.

[4] This is the principal Means by which crude Chyle is digeſted into animal Fluids, namely, by forming it into Blood, compacting and agitating the ſame. The Blood which has ſuffered the Action of the Lungs and Arteries, paſſing through the Fibres of the Auricles and Threads of the Ventricles, will be therefore extremely fluid, and in the Spleen it will undergo a new Action related to that of the Arteries; and therefore it will be rendered the moſt apt for moving freely that can be poſſibly produced by the Mechaniſm of the human Body.

[5] The Structure of the Spleen appears (by §. 319, 320, 321.) to be the ſame with the Corpora cavernoſa Penis; and therefore there is no Objection why the Motion of the Blood ſhould not be alike in both; that is, for the Blood to be poured out of the Arteries into the Cells, and then to be again abſorbed by the open Mouths of the Veins; for it is well known that in the Penis the Blood is poured out of the Arteries into the cavernous Bodies where it is retained by the Compreſſion of the returning Veins preventing its reflux, which Compreſſion being removed, it is again received into the Veins by their Openings. The Intentions of Nature are in theſe Caſes different, but the Mechaniſm appears to be the ſame.

[6] It was ſaid before, (§. 322.) that the Spleen received more Nerves than any other Viſcus, for which no other Uſe could be aſſigned than to pour in their Spirits to the Blood. But as there are no nervous Veins to be ſuppoſed, therefore the nervous Juice will be retained, mixt and elaborated with the Blood.

[7] Therefore the Functions of the Spleen ſeem to be, 1. To diſtribute the arterial Blood attenuated by

the Heart, Lungs and Arteries, and to diſpoſe it to paſs through the infinite Ramifications of the ſmalleſt Arteries in its Compoſition. 2. To apply the Power of Reſpiration, or rather Effects of the like Nature, to the Blood in this Viſcus; ſince the Spleen is attached to the Diaphragm, and is every way obedient to the ſtrong Preſſures communicated from the circumjacent Parts. 3. To return the Blood thus prepared partly through the Veins, as in the other Viſcera, and partly to pour it out of the Arteries into the Cells to agitate it by the Force of Reſpiration, to dilute it by a Quantity of arterial Lymph ſeparated by the ſmall Arteries which run upon the Cells and upon the Glands, proper to the Spleen itſelf; and laſtly, to dilute it with the nervous Juice, and return it thus changed into the Vena Portarum. The great Uſe of it therefore to the human Body, is to prepare the Blood that it may be extremely fluid, and by mixing with the more ſlowly moving Blood of the Porta, render it fitter to circulate; in one word, to be a Diverticulum or Sinus to the Porta, as the Lungs are to the Heart; that is, to prepare the Blood in ſuch a manner by its arterial Fabric, as to render it capable of paſſing freely through the ſmalleſt Veſſels of the Liver.

§. 324. The Blood being thus attenuated, diſſolved and mixed with the Lymph and Spirits, ſo as to be highly *ſubtilized* [1] by theſe Cauſes, (§. 323.) will not eaſily coagulate, but remain intimately mixt, without being apt to *concrete* [2] or ſeparate into diſſimilar Parts; it will alſo remain of a *purple* [3] red, in the ſame manner as we obſerve it when extravaſated from a large ſplenic Vein in this Part.

Which

[1] Which Blood was but a little before expelled from the Heart, having parted with none of its more fluid Juices; but is diluted with arterial Lymph, repleniſhed with nervous Juice, and as yet retains the Impreſſion which it received from the Lungs and Reſpiration.

[2] The Blood which has been diſcharged by cutting the carotid Arteries of an Ox after the manner of the *Jews*, immediately congeals; but the Blood which comes from the Spleen retains its Fluidity a long Time, nor does the Craſſamentum eaſily depart from the Serum.

[3] Which purple Colour the Ancients compared to a Blackneſs.

§. 325. This (§. 324.) therefore is the proper Action of the Spleen, which for that Reaſon has no *excretory Duct* [1], like other Viſcera, by which they diſcharge ſome particular Humour that has been ſeparated by their Fabric; but it returns all the Blood and Humours intimately mixt together.

[1] In the ſame manner as the Lungs have no excretory Duct: for in the Lungs and Spleen, the Vein ſerves for an excretory Veſſel to return the Blood after it has undergone the Efficacy of thoſe Viſcera. I make no doubt but that there is a Vein ſtill to be diſcovered in this Viſcus, which ſerves only for returning the Blood, which has been ſubſervient to its Nutrition; and with that Vein there muſt be alſo a correſponding Artery. Of this we have a notable Inſtance in the Lungs, where we find a diſtinct Artery from the pulmonary, which ſerves for conveying Blood for the Nutrition of the Lungs; whereas the pulmonary Artery with its correſponding Vein, only tranſmits the Blood from

one Side of the Heart to the other, to receive the Impreſſion of the Lungs for the good of the whole Machine: therefore beſides this, there is alſo the Arteria Bronchialis, which with its correſponding Vein, ſerve for tranſmitting and returning the Blood proper to the Nutrition of the Subſtance of the Lungs themſelves. The ſame Mechaniſm of Nature was alſo latterly diſcovered by *Ruyſch* in the Inteſtines.

§. 326. From hence it manifeſtly appears, that the whole Benefit of the Action of this Viſcus is not for its own Service; but as all its Humours are tranſmitted by the *ſingle* [1] Vena Portarum to the Liver, it is therefore evident that the Uſe of the Spleen is to be ſubſervient to the *Liver* [2], and that therefore its Uſe cannot be fully explained, until we have firſt examined the Office and Uſes of the Liver.

[1] From hence it is demonſtrated, that the Spleen does not labour for the whole Body, but for the Liver only: for if it operated for the common Uſe of the whole, it would then tranſmit its Blood, not to the Vena Porta, but to the Cava; but there was never yet a Vein diſcovered paſſing from the Spleen to the Cava.

[2] In the Liver the venal Blood performs the Office of that of the Arteries, as it enters that Viſcus through Veſſels which are converging like Arteries: but the Obſtacles or Reſiſtances of theſe ſmall Veſſels could not be overcome by the Blood, unleſs it was aſſiſted by ſome Machine communicating the ſame degree of Fluidity to it, as the Blood in other Parts receives from the Action of

the Arteries. For this Reaſon alſo the Blood returns into the Heart, which was not capable of overcoming the Reſiſtance of the Arteries ramified from the Aorta: but to enable it to overcome thoſe Reſiſtances, the Lungs elaborate the venal Blood into the nature of arterial. What the Lungs perform in regard to the Aorta, that does the Spleen perform to the Blood in reſpect to the Vena Portarum: for in both Caſes the venal Blood, namely, that of the pulmonary Vein, and of the ſplenic Vein, has all the Properties of the beſt arterial Blood.

§. 327. From this Doctrine of the Uſe and Fabric of the Spleen, many things may be underſtood, which are otherwiſe very obſcure, and which may ſerve as a Confirmation; ſuch, as for Example, are thoſe which follow:

What the Deſign is of the *Situation* [1], *Bulk* [2], and pendulous *Suſpenſion* [3] of the Spleen, and Action of the adjacent Parts thereon?

What is denoted by the Situation, Origin, and Capacity of the ſplenic *Artery* [4]?

Why and how long an Animal becomes more *ſalacious* [5] after the Spleen has been cut out? This is evident from the Situation of the ſpermatic Arteries.

Why the Spleen being cut out, is followed by a more frequent voiding of *Urine* [6]? This is evident from the Vicinity of the renal Artery.

Why the Animal becomes more *voracious* [7], who has the Spleen extripated? This appears from the Situation of the cœliac Artery.

What is the Cauſe of the *rumbling Noiſe*[8] or Belchings, with Vomiting and Sickneſs, which follow for ſome Days after the Spleen has been extripated? This is alſo evident from the preceding, and from the Situation of the ſtomachic and ſplenic Nerves.

Whence ariſes the *Tumour*[9] of the right Hypochondrium, and Enlargement of the Liver, after the Spleen has been removed?

Why *ſplenetic*[10] and hypochondriacal Patients have all the forementioned Symptoms, with a Paleneſs?

From what Cauſe thoſe Patients are more prone to *Laughter*[11]?

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[1] With reſpect to the Veſſels of the Spleen, it was neceſſary for them to ariſe before thoſe of the Liver, ſince this Part prepares its Blood for the Liver. But with reſpect to the Situation of the Viſcus itſelf, its Nature and Office required it to be placed near the Heart, contiguous to the Diaphragm; and ſo attached to the Stomach, that when that is diſtended with Aliment, the Spleen will be conſequently compreſſed alternately, as it alſo will be by the Action of the Diaphragm and abdominal Muſcles. For in this Part of the Abdomen, the Tendons and Inſertions of the oblique and tranſverſe Muſcles meet together, and, as it were, terminate their Action in a Center.

[2] Its Bulk is conſiderable enough, if you obſerve that it is not made up with Fat or Muſcles, but of Arteries, Veins, and Nerves only, without any excretory Ducts.

[3] This in order that it might be preſſed equally on all Sides, leſt if it ſhould have been fixed to the

Back, it might in that Part have been deſtitute of its Preſſure.

[4] Theſe Arteries are very near to the Heart, and the largeſt of thoſe belonging to the abdominal Viſcera, quite free through their whole Courſe, and continually ſubjected to the Efficacy of Reſpiration, by which means they convey their Blood as plentifully and ſwiftly as poſſible to the correſponding Veins.

[5] *Malpighi* and *Bohn* cut out the Spleen in Dogs, having firſt tied the Veſſels to prevent a dangerous Hæmorrhage; and after healing up the Wound of the Abdomen by Suture, they obſerved the following Events: 1. That thoſe Dogs were extremely lecherous; and this becauſe the Blood of the Aorta being denied a Paſſage into the conſiderable ſplenic Artery, therefore flowed more plentifully into the Spermatics; whence a greater Quantity of Semen being ſecreted, therefore the Appetite of diſcharging that Humour was alſo increaſed. But this Salacity is but of a ſhort Duration; for the Animal cannot long ſurvive in a healthy State, under ſo great an Injury offered to the Liver.

[6] They in the ſecond place obſerved, that the Animal voided his Urine more frequently, plentifully, and watery; and this for the ſame Reaſon which we laſt mention'd, namely, a more copious Determination of the Blood into the emulgent Arteries, as well as into the Spermatics.

[7] Thirdly, The Animal became more voracious, as well from the increaſed Secretion of the gaſtric Liquor, from whence Hunger in ſome meaſure ariſes (*per* §. 88.) as from the greater Efficacy or Action of the muſcular Coat of the Stomach. This likewiſe ariſes from the ſame Cauſe, namely, the Blood which went into the Cœliac being excluded

from the ſplenic Branch, therefore enters in a larger Quantity through the Mouths of the four arterial Branches, which come from the Cœliac, and are ſpent upon the Stomach. But neither is this Voracity of any long Duration, ſince the whole Preparation of the Chyle is thus injur'd, by removing this important Viſcus.

[8] Such Tumults were obſerved in the Abdomen, that the Animal has been obſerved to be frighten'd out of his Sleep with the Noiſe, and to prick up his Ears, looking round, to learn from whence ſo great a Diſturbance proceeded. Theſe flatulent Diſturbances ſeem to ariſe from the Perverſion of the Blood's Courſe through the Inteſtines, by which their Contents are hurried on by an Increaſe of the periſtaltic Motion, and the confined Air being accumulated, is exploded or diſcharged at particular Times; the Cauſe of all which Diſturbance is the Blood's flowing into the meſenteric Arteries in an increaſed Quantity.

[9] It is obvious to every body, that when the Spleen has been cut out, the Liver will be more turgid; which would therefore ſeem to infer, that the Blood of the Spleen did not paſs to the Liver. But we only learn from this Experiment, (1.) That the hepatic Branch of the cœliac Artery receives more Blood from the Deſtruction of the ſplenic Artery. (2.) That the Efficacy of the Spleen in diluting and attenuating the Blood being deſtroyed, therefore the Blood flows more difficultly through the Liver, ſtagnates and obſtructs the Veſſels, and by that means diſtends this Viſcus to a morbid Bulk. Therefore three or four Months after the Spleen has been cut out, the Liver will be ſwell'd, and a Tumour formed in the right Hypochondrium, which muſt be troubleſome to the Animal.

[10] By this Name the Ancients call thoſe People, who waſting in their whole Habit beſides, ſuffer an Enlargement of the Spleen; though from the Seat of the Diſorder they have been rather termed by the Moderns hypochondriacal People. In ſuch Perſons there is a leaden Colour of the Face, accompanied with all the Symptoms which were before mentioned to follow in an Extripation of the Spleen in Dogs. They are ſalacious, and diſcharge their Semen even to a Weakneſs in their Sleep, that is, in the Beginning of the Diſeaſe; for when it is confirmed, they are more cold in this reſpect. They diſcharge much Urine, which is watery; they are voracious, abound with Flatulencies, which they diſcharge with a conſiderable murmuring; and laſtly, as we ſaid before, the Liver itſelf ſwells; a Tumour of which is always obſerved in Men who are extremely ſplenetic.

[11] It has been obſerved, that Actors, who get their Living by procuring the Laughter of the Publick, being full of Geſture and Facetiouſneſs, are alſo ſalacious, and generally hypochondriacal, being ſcarce able to contain themſelves in Spirits, until they return again to their ridiculous Entertainment of the Publick. It does not ſeem an eaſy matter to explain Laughter. What it is in the Nerves we know not, but perhaps another Age may know more of it; but this we can tell, that the Mind puts the Parts in a Poſture of laughing at the ſudden Appearance of any thing which is abſurd. As to the Cauſe of it in the Body, it is placed in ſome Diſpoſition of the Diaphragm, which being inflamed cauſes involuntary Laughters. Therefore the Laughter to which hypochondriacal People are inclined, may be accounted for from the Regurgitation of the Blood into the adjacent phrenic Arteries, as being ob-

ſtructed in the Branches of the ſplenic Artery; while at the ſame time the Spirits flow back in the ſame manner from the ſplenic Nerves into the adjacent Nerves of the Diaphragm.

§. 328. We may alſo from hence be able to judge, whether the Spleen is formed only as an *Equipoiſe* [1] to the Weight of the other Viſcera, and to ſtop up a Cavity? Whether it is an *uſeleſs Maſs* [2] of Matter? Whether it is an *Error* [3] committed by Nature in a Lethargy? Whether it is to ſerve as a *Sink* [4] or Cloſeſtool for clearing the Blood of its atrabiliary Fæces? Whether it is the Seat of a *Ferment* [5], or of a Fire-place, or the vital Heat, by whoſe Rays the digeſtive Power of the Stomach is excited? Whether or no it is the Seat of Luxury and Lechery, as well in thoſe who are awake, as in thoſe who are ludicrous in their Dreams? Whether or no this Part being diſordered, diſturbs the *procreative* [6] Faculty, and renders the Perſon ſterile? Whether this is the Seat of Indolence and Reſt, or *Sleep* [7]? Or whether the Ancients more rightly make it to be the Throne of Laughter, *Joy* [8], and Mirth? In ſhort, all theſe Conjectures muſt be diſſipated by the Light which *Malpighi* has given us by his Obſervations on the Fabric of this Organ. Nor is the Opinion of *Gliſſon* more probable than the former, who once imagined the Spleen to be a ſecond Reſervoir to the *nervous Juice* [9], to be taken up and ſent from thence by its many Nerves. Nor has that Opinion any more Foundation, which ſuppoſes that all the

Blood receives its greateſt Perfection in this Part[10].

[1] Several of the Ancients have taught, that the Spleen was formed to act as a Weight in pulling the Diaphragm downward on the left Side, as the Liver does on the right. But in this they injure the Honour of the divine Architect, ſuppoſing him to have no other Deſign in the forming of this Part than to fill up a Cavity. For Symmetry does not appear to have been ſtudied by the Architect in the internal Parts, which are never expoſed to Sight; and therefore Nature has very well ſpared herſelf the Pains of an exact Symmetry in the Heart, Stomach, Pancreas, Meſentery, Spleen, *&c.* where it would have been quite uſeleſs. In ſhort, the Duplicity of many Organs is not made for the ſake of Symmetry, but that the Animal might enjoy the Benefit of one Part, which is of the laſt Importance, if he ſhould by Accident be deprived of the other.

[2] It is a little wonderful, that many wiſe Men among the Ancients ſhould be perſuaded that God and Nature make nothing in vain, and yet that ſome of them ſhould ſtupidly ſuppoſe the Spleen to be a mere Weight: for certain it is, that every, even the leaſt Part of the human Body contributes ſomething to the common Good of the whole.

[3] Drunken *Prometheus* feigned the Spleen to be an Error of Nature; an Opinion certainly as fooliſh as impious.

[4] *Galen* and almoſt all the Schools after him, have built upon this Syſtem, that all the Chyle neceſſary for Life and Nutrition, was taken up by the meſenteric Veins and conveyed to the Liver; but that this Chyle was as yet a crude Liquor and very foreign to our Nature: but yet that all the

Parts which were nutritious in the Chyle, were conveyed to that very bloody Viſcus the Liver, and there formed into Blood. But the Chyle being ſtock'd with a large Quantity of Fæces, it was neceſſary for them to be firſt ſeparated, before the reſt could be formed into radical Moiſture: Hence therefore that there was a Separation made of two Sorts of Excrements in the Liver, the one yellow Bile, which flows into the Duodenum and tinges the Fæces; the other a malignant or black Bile, the worſt of all Excrements, which is conveyed to the Spleen there depoſited and collected, that it might not prove the Cauſe of great Diſorders in the human Body. But all this we have in part refuted before; and it is in part repugnant to the known circulating Courſe of the Blood; by which we are taught, that nothing is conveyed from the Liver to the Spleen by the ſplenic Vein, but on the contrary, that all the Blood of the Spleen flows to the Liver, as is evident from the Structure of the Veſſels, as well as from Experiments made on living Animals. Add to this, that the Blood of the Spleen is ſo far from being feculent, that it exceeds all the reſt in Fluidity and florid Colour.

[5] *Baſil Valentine*, *Iſaac Hollandus*, *Paracelſus*, *Helmont*, and the reſt of the chemical Sect, oppoſed the Schools with their new Syſtem, ſuppoſing that there was no Change wrought in the internal Parts of the human Body without Fermentation. That in the Stomach the crude Aliment was converted into Chyle by a Ferment, which the Stomach ſtood in need of. Moreover, that theſe Ferments were all acid; but yet that this Ferment could not be generated in the Stomach itſelf, from whence the Source of it would ſoon be waſhed away or deſtroyed; and therefore that there could be no Viſcus which was able to ſupply this Fer-

ment to the Stomach beſides the Spleen. The Spleen then they made the ſecretory Organ of a vital Acrimony or Ferment, which was conveyed into the Stomach by the Vaſa Brevia, and there proved the principal Cauſe of Digeſtion. But even *Helmont* himſelf confeſſes, that a true Acid is not natural nor indigenous to any Part of the human Body, but is rather an Enemy; and therefore ſuch cannot be ſeated in the Spleen; beſides, nothing can flow from the Spleen to the Stomach by the Laws of the Circulation, but on the contrary, the Blood is carried from the Stomach by the Vaſa Brevia into the ſplenic Vein. But if any one ſhould aſk why there are ſo many Communications betwixt the Veins of the Stomach and thoſe of the Spleen, we anſwer, that the Stomach is a Viſcus ſo alterable, that it may be much diſtended by the Food, ſo as in a great meaſure to intercept the Circulation, by compreſſing its Arteries, and produce the worſt Conſequences: To prevent which, Nature has placed Veins all round the Stomach, into which the Arteries may very ſpeedily evacuate themſelves, by ſending their Blood into the large unreſiſting ſplenic Vein.

[6] This was alſo an Hypotheſis of *Helmont*, which has been long ago refuted by *Malpighi*, from whoſe Experiments it appears, that Animals who have loſt their Spleen are more prolific and inclined to Venery.

[7] Alſo this Opinion ſeems to have been ſtarted by *Helmont* for no other Reaſon, than becauſe thoſe People ſleep well who have their Spleen in a healthy Condition, while thoſe who are ſplenetic are reſtleſs. But this Watchfulneſs ariſes no more from the Spleen than from all the other Viſcera when obſtructed: for the obſtructed Spleen does not deſtroy Sleep from any peculiar Diſpoſition of itſelf,

but only becauſe the Blood obſtructed below is ſent up in a greater Quantity to the Brain. For the ſame Reaſon likewiſe, if the Feet are cold and the Head hot, as frequently happens in ſtudious People, they can never fall into a Sleep till their Feet are firſt become warm.

[8] It is an old Saying, that the Spleen cauſes Laughter. But whether this aroſe from an Obſervation that ſplenetic Perſons are generally croſs, is a Queſtion; but this is certain, that Joy depends much upon a free Circulation of the Blood through all the Viſcera and Veſſels of the Body, which being obſtructed, produces Anxieties, and an uneaſy Senſe to the Mind. Therefore it may be fairly concluded, 1. That the Spleen being ſound and free from Obſtructions, conduces ſomething to the Alacrity of Animals; ſince it attenuates and renders the Blood fluid, that it may eaſily pervade the Parts which are in the greateſt Danger of Obſtruction: and, 2. For the ſame Reaſon Sadneſs will follow if the Spleen is obſtructed, ſince itſelf will be invaded with an obtuſe Pain or Anguiſh, and will not attenuate the Blood as uſual, and as is neceſſary to perfect Health.

[9] This Gentleman ſuppoſes the Spirits to be drained from the Blood into the Cells of the Spleen, and that from thence they were abſorbed by the ſplenic Nerves. But this Hypotheſis he afterwards abrogated as we obſerved before.

[10] This was the Hypotheſis of *Sylvius*, namely, that the Spleen elaborated the Blood, rendered it very ſubtle, fluid, full of Spirits, and in a manner more than perfect, that it might correct the reſt of the Blood with which it mixed in the Body. He was right in thinking that the Blood of the Spleen was beſt conditioned, and in a manner more perfect or ſubtilized than that of other Parts of the Body;

but he was out in his Doctrine, that the Blood of the Spleen was to correct the whole Maſs; ſince all the Blood of the Spleen is conveyed only to the Liver; whence it follows, that the Spleen labours only for the Liver, to which it is a kind of Lungs, and that it does not immediately work for the general Syſtem of the whole Body.

The Action of the OMENTUM.

§. 329. BUT while the Blood (§. 324.) thus prepared, flows from every Part of the Spleen by ſeveral Veins into the great *ſplenic* [1] Branch, in order to paſs on through the Vena Portæ to the Liver, it there meets in its Courſe and mixes with the venal Blood returning from the Omentum by its proper *Veins* [2]; and this Mechaniſm we ſee conſtantly obſerved by Nature as a Law.

[1] This large Vein runs parallel to the Horizon, being ſingle all the Way of its Courſe, and inſerted into the large Vein of the Meſentery. At the Place of this Inſertion there is a ſurprizing Conflux of different Veins, as they are elegantly expreſſed by Tables of *Veſalius* and *Euſtachius*.

[2] Which are called Adipoſa or Epiploica, one in each Side, which return only the Blood which has been elaborated in the Omentum, the Blood of which Viſcus is conveyed into the ſplenic Vein, and from thence into the Vena Portæ. Therefore the Omentum ſeems to labour wholly for the Liver, to which it tranſmits all its Blood.

§. 330. If we conſider the *Connection* [1], Situation, Structure, and Inſertion of the Omentum with its great *Tenuity* [2], which is compared to a Web of the fineſt Silk, by *Malpighi*; and if we alſo compare its Structure with the Diſcoveries which have been made by the Induſtry of Anatomiſts in ſeveral Kinds of brute Animals, we ſhall find, that from the Arteries of the Omentum, which are diſtributed into very minute reticular Plexus's upon the Surfaces of the *Cells* [3] or Bags which contain the Fat, upon which Cells they terminate in ſmall Veins diſpoſed in the like Order: I ſay, we ſhall find that a thin and ſubtle Oil is ſeparated by lateral Ducts from thoſe Arteries, and conveyed into the adipoſe Cells, where it is collected, retained, and highly attenuated by the continual Warmth, Motion, and Attrition, ſo as to become more volatile, acrimonious, and like unto the Bile; ſo that at length this collected and thus prepared Oil is expelled from the communicating Cells of the Omentum through certain open Ducts into the Veins, which convey it to the *Liver* [4], where it alſo mixes with the Blood that comes thither from the Spleen.

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[1] The Omentum is a thin Membrane, which deſcends from the lower Edge or Bottom of the Stomach down to the Navel, where it again aſcends backwards up to the Colon, into which it is inſerted; ſo that its Plates form a Bag, in which there is an empty Cavity called the Duplicature of the Omentum. This membranous Bag is not only

ly ſpread over the Inteſtines, but it alſo inſinuates itſelf betwixt the Convolutions of the Inteſtines, and ſometimes it even adheres to the Meſentery. Now it is within the Cavity of thoſe two Membranes that all the Veſſels of the Omentum are ſeated. *Veſalius* has given us a Figure of this Part, which *Euſtachius* perceiving to be true, has not oppoſed it with any other of his own. But the Cavity betwixt the two Plates or Membranes has been diſcover'd by *Winſlow*, after making a ſmall Wound through one of them, and inflating with a Blow-pipe. Beſides theſe principal Connections of the Omentum, it alſo adheres to the Pancreas, Duodenum, Spleen, the Bottom of the hepatic Veſſels, and to the Meſentery. It is ſpread in ſuch a manner under the Peritonæum, that no Part of that Membrane in the Abdomen can be applied naked to the Stomach or Inteſtines; ſo that it is no eaſy matter for them to be injured in violent Motions of the Abdomen. For there is a continual Attrition betwixt the Peritonæum and the Viſcera contained in the Cavity of the Abdomen, when the Viſcera are either preſſed downward againſt the Peritonæum by the Deſcent of the Diaphragm in Inſpiration, or when the Peritonæum preſſes itſelf againſt the Inteſtines by the Contraction of the abdominal Muſcles, ſo as to return the Viſcera upward and backward. The Omentum is therefore interpoſed, as being ſoft and ſpungy, to infringe and break off the Violence of the Preſſure betwixt theſe Parts. It does not deſcend uſually much lower than the Navel, becauſe the Force of Reſpiration is but weak in the lower Part of the Abdomen.

[2] If the Fat and Blood-veſſels are removed from this Membrane, its Tenuity will appear almoſt in-

credible,

credible, inſomuch that *Ruyſch* pronounces that there is not a thinner Membrane to be found.

[3] The Microſcope demonſtrates, that the ſmalleſt ſanguiferous Arteries are continued into little Cells full of ſubtle Oil; of which Cells almoſt the whole Subſtance of the Omentum is compoſed: for if the Fat is exhauſted or melted out from them, which ſometimes happens in brute Animals, there then only remains a thin ſhriveled-up Membrane.

[4] It was equally neceſſary for the Fat to have Ducts to carry it as well from, as into the Cells. For as it is perpetually brought by the arterial Blood, and yet the Omentum does not grow to an immenſe Bulk; it therefore follows, that as much of the Oil muſt paſs off ſomewhere by the Veins, as there is brought of it by the Arteries. But for this purpoſe we find no other reductory Veſſels beſides the Veins; and therefore the Oil of the Omentum muſt be conveyed by the Veins to the Liver, ſince that is the Part into which theſe Veins diſcharge their Blood. It is therefore highly probable, that Part of this Oil goes to the Formation of the Bile, after it has been elaborated, attenuated, and in ſome degree turned rancid and bitter in the Omentum, which ſuffers the Efficacy of Reſpiration, and of the periſtaltic Motion of the Inteſtines. *Malpighi* has even demonſtrated to the Eye, that the Fat is conveyed by particular Ducts to the Liver in brute Animals, as in Frogs and Fiſh. But notwithſtanding this, I alſo allow that there is an Evaporation of the more ſubtle Part of the Oil through this Membrane, which like an oily Vapour inſinuates betwixt the Convolutions of the Inteſtines, and betwixt them and the Peritonæum, to lubricate and facilitate their Motion, and prevent them from growing either to each other or to the Peritonæum.

§. 331. It alſo appears probable, that an Exhalation of Vapours extremely ſubtle, and apt to be imbibed again, inſinuates itſelf into the whole Omentum, in the Form of a fine Vapour, after it has been exhaled from the Mouths of the innumerable ſmall Veſſels, which are diſtributed through the Omentum, whoſe Membranes are extremely thin; which Vapours inſinuating themſelves into the Omentum, are continually ſupplied by the ſubtle Dew diſtilled into the warm Cavity of the Abdomen from the very minute Orifices of the exhaling *Veſſels* [1]; and by theſe oily Vapours, the Surfaces of all the Parts contained within the Peritonæum are continually moiſten'd, lubricated, and mollified. But we muſt neceſſarily ſuppoſe this Vapour to be extremely ſubtle and volatile, if we conſider its Nature, Origin, continual Waſte and Supplies, with a Smell which it affords upon opening the Abdomen of an Animal that is warm.

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[1] *Ruyſch* has found, that by carefully taking out the Omentum from young Animals and drying it, it appears perforated on all Sides with very ſmall Pores. And beſides this, the Abdomen in all Animals is continually repleniſhed with moiſt Vapours, which affect the Noſe with a peculiar rank Smell differing in each kind of Animal. The Vapour we now ſpeak of, exhales continually; and yet we do not obſerve it accumulated into Water, ſince in the Bodies of People who have died in Health, all the Viſcera appear lubricated with a thin Oil without any Water extravaſated. There-

fore as it continually exhales, it muſt alſo be continually abſorbed, and there muſt be venal Ducts for the Abſorption correſponding to thoſe arterial Ducts, from whence the Vapour is exhaled; and by this Artifice only could Nature prevent the Parts from becoming dry, without ſuffering any Quantity of Water to be accumulated. A Defect of the Secretion of theſe Vapours will render the Parts dry and rough; and a Defect in their Abſorption will cauſe a Dropſy or Aſcites. But there does not ſeem to be any Organ better adapted for this Abſorption than the thin Plates or Membranes of the Omentum, to draw in the abdominal Vapours by the very patulent Mouths of the Veins, in the ſame manner as we find the Oil or Fat exhaling from the Veſſels of the Omentum, (§. 95, 330.) Hence it is that we have no Inſtance of a dropſical Body with a ſound Omentum. Hence then this ſemiputrid highly attenuated Vapour, which is one of the moſt volatile of the animal Humours, ſeems to be abſorbed by the ſmalleſt Veins of the Omentum, which return it into the larger epiploic Veins, from whence it paſſes into the Vena Porta. This Doctrine is alſo confirmed, as well by the Return of the Water in dropſical Patients, as by an Experiment deſignedly made by *Nucke.* He made a ſmall Inciſion in the Scrotum of a live Dog, ſo as to form a Paſſage into the Cavity of the Proceſs of the Peritonæum, which in that Animal affords a free Entrance into the Abdomen: By this Wound he injected ſeveral Ounces of warm Water, ſewing up the Abdomen afterwards, ſo that none of it could eſcape, and tying up the Dog in his Chamber, upon the Floor of which there was not ſo much as a drop of the Water ſpilt. The Dog diſcharged a large Quantity of Urine, and upon opening his Abdomen ſome Days afterwards, there was not any extravaſated Water to be found; which is a certain Sign of the ſpeedy Abſorption which is here made.

§. 332. But as the Omentum is not obſerved to have any other excretory Veſſels in Man, except two Veins which are called the right and left Epiploic; it is therefore probable, that the venal Blood of the Omentum, repleniſhed with the Lymph (§. 331.) and the Oil (§. 330.), are all intimately mixed and conveyed together to the *Liver* [1].

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[1] Thus therefore the Uſe of the Omentum in the human Body appears gradually more and more manifeſt, namely, for its Fat or Oil, which is become ſubtle, rancid, and bitter by the perpetual Warmth and Attrition, to be conveyed into the Liver for forming the Matter of the Bile, to be there ſeparated from the venal Blood. This Doctrine is confirmed by the Obſervations of *Malpighi*, who ſaw adipoſe Ducts in Frogs, which being preſſed apparently diſcharged Drops of Oil into the Vena Portæ. Hence it is that the Livers of Fiſh are in a manner buried in Fat, and the Liver of a Cod-fiſh diſcharges a mere Oil by Preſſure, and even almoſt entirely melts into Oil. For as theſe Fiſh are very voracious, and live in a cold Element, they therefore require a very large Quantity of an exceeding bitter Bile. Nor ought it to be objected, that it does not ſeem probable, ſo ſmooth a Fluid as Oil ſhould be elaborated into a Humour ſo extremely bitter as the Bile: for all Oil itſelf becomes yellow, acrid, and in time very bitter, barely by Heat and Attrition, as we are taught by chemical Experiments. Even the Fat

of Aliments, which having lain too long a time upon a weak Stomach, receives the like Alteration in a very ſhort Space, ſo that it is belched up under the Form of an exceeding bitter, rank, and yellow Oil, inflammable in the Fire. But the ſecondary Uſe of the Omentum is, as we ſaid before, to exhale a thin Oil, continually to lubricate and facilitate the Motion of the Inteſtines; after which it is abſorbed again with the putrid Vapours.

§. 333. From hence we may underſtand, why the Omentum grows to ſuch an immenſe *Bulk* [1] in Animals that live at Reſt? Why, on the contrary, this Part is quite thin and membranous, and its Veſſels rather filled with a Humour which appears like *Serum* [2] than Oil in Animals addicted to too much Labour? And why alſo its Veſſels are almoſt continually filled with a thin Serum in emaciated and dropſical Subjects? And laſtly, it appears that there is a greater Derivation of the collected Oil of this Part into the ſplenic Vein, in proportion as the Blood's *Motion* [3] is increaſed. It alſo appears, why the Omentum is faſtened near all the Viſcera which are *deſtitute of Fat* [4].

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[1] A certain rich Citizen, who took Pleaſure chiefly in the Gratification of his Appetite, having his Food and Drinks prepared in the moſt exquiſite Manner, grew ſo fat that he was obliged to ſupport his Belly by a Saſh hung over his Shoulders; nor was he capable of ſitting at Table ſo as to reach with his Hands, unleſs where there was a round

Part of the Table cut out to receive his Belly. After the Death of this Perſon, the Omentum being cut out, weighed thirty Pounds. Thus alſo in Hogs, Calves, *&c.* before fattening, the Omentum is as thin as Paper; but after a few Months it becomes ſo fat, as totally to obſcure the Blood-veſſels. For in the Omentum the Blood's Circulation is very ſlow, if it is not forwarded continually by the Reſpiration: But the Motion of the Arteries is always ſtronger than the Reſiſtance of the adipoſe Cells; and therefore when the beſt or moſt oily Part of the Chyle is continually conveyed through the Arteries, while nothing is returned but the mere Blood by the Veins; it follows, that all the Fat or oily Parts of the Chyle muſt be poured into the looſe Cells, into which the Arteries open.

[2] In a Poſt-Horſe the Omentum is thinner than the fineſt Poſt-paper, which we generally uſe for Letters, upon the Account of its Lightneſs: for by the continual and ſtrong Attrition which is made upon this Part, the Oil is ſo attenuated as to partly exhale in the former Vapours, and partly to be abſorbed or preſſed into the Veins, which return it into the Blood. Even by the violent Exerciſe of a Horſe which has been fatten'd in the Stable, *Ruyſch* has obſerved the Cells of the Omentum to be burſt open, by the hard running of the Animal; by which means Death has followed in a little time, and many Pounds of true Oil were found extravaſated in the Cavity of the Abdomen.

[3] Thus it is in the Omentum of old people, and thoſe who are emaciated or dropſical: for in theſe the Place of the conſumed or exhauſted Oil is ſupplied by the ſtagnating watery Vapours which are abſorbed. For the firſt Sign of a Dropſy is a certain gelatinous Humour collected in the adipoſe

Cells,

Cells, as has been demonſtrated in the arachnoide Membrane of the Brain itſelf in a diſeaſed Body: But ſo ſoon as the Water has enter'd the Cells of the Omentum, it then putrifies in a very ſhort time.

[4] The Attrition is at that time the greateſt, by which the Blood inclines to the moſt intenſe lixivial Acrimony, the Bile becomes alſo more acrid, and all the Humours require more of the obtunding Oil to ſheath the actuated Salts. Nothing is therefore more ſuitable than oily Emulſions, whenever the Blood degenerates into an acrimonious or corroding State by acute Diſeaſes, which actuate its Salts, and render its oily Parts rancid. And this is the Reaſon, as *Malpighi* well obſerves, why Nature has more bountifully ſupplied thoſe Parts with Fat or Oil, where there is the greateſt Attrition, or where the Humours are more acrimonious.

[5] Such as the Peritonæum, Surface of the Inteſtines, Stomach, and the convex Part of the Liver and Spleen: for all theſe Viſcera are lubricated, and prevented from rubbing ſo as to injure each other by their Contact. But it is not joined to the Meſentery, becauſe that is naturally repleniſhed with its own Oil.

§. 334. But with this Blood (§. 324.) is alſo mixed that which returns from the Membranes of the Stomach by the *Vaſa brevia* [1], the Gaſtrica major and the Gaſtro-epiploica, both right and left, and the Pylorica; all which Blood being deprived of that Lymph which it diſtils into the Cavity of the Stomach, does therefore mix in ſeveral Places with the Blood returning from the Omentum (§. 332.);

and perhaps it carries with it a good deal of the moſt ſubtle *Humours* [2], which have been derived from the thinner Juices of the Aliments abſorbed by the Veins of the Stomach. Hence the Reaſon is alſo evident, why the venal Blood of the Stomach diſcharges itſelf by ſuch a great Number of Veſſels, diſtributed according to its Length; to wit, that the Diſcharge of this Blood might not be impeded by the Diſtention of the Stomach, when filled with Aliments; whereas its Courſe might have been eaſily ſtopped, if it had been diſcharged by one Vein only.

[1] The Stomach is ſo formed that it may be capable of a great Alteration in the Dilatation or Contraction of its Capacity; and therefore there would be Danger of compreſſing its Veſſels in ſudden Diſtentions, ſo as to intercept the Blood's Circulation as often as it is filled with Aliments; nor was it poſſible for the Veſſels to be commodiouſly inſerted near the Orifices of the Stomach, ſince when it is filled they are brought near to each other, and therefore the Veſſels would conſequently have been there compreſſed (§. 85.) But to prevent this, Nature has provided (1.) that the Stomach ſhould be furniſhed, not with a ſingle arterial or venal Trunk, but with ſeveral ſmaller ones, that if one Veſſel ſhould be compreſſed, the reſt might remain pervious. (2.) She has ſo conjoined theſe Veſſels with each other by Anaſtomoſes, that if the Blood is obſtructed by the Compreſſion of one Veſſel, it can continue its Courſe on through the other Veſſels with which it communicates. One Claſs of theſe Blood-veſſels of the Stomach are ſix or eight Veins called Brevia, conveying the Blood

from the bottom of the Stomach to the ſplenic Vein, for about the Length of an Inch; for this was the ſhorteſt Courſe for the Blood to return into any conſiderable Trunk.

[2] We ſaid before (§. 87.) that it was probable the moſt ſubtle Particles of the Saliva, Aliments, and ſpirituous Liquors, with the animal Spirits transfuſed into the Stomach, were continually abſorbing by the bibulous Pores which open in the Surface of that Organ; but whatever is obſorbed by theſe Orifices paſſes into the Veins of the Stomach, which conſequently ſend their Contents to the Vena Portæ.

§. 335. But beſides theſe, there are alſo other ſmall Branches returning the venal Blood from the Pancreas, which are alſo followed by the internal *hæmorrhoidal*[1] Veins: which alſo ſend their Blood to the Liver, perhaps more abundantly repleniſhed with *acrid Particles*[2].

[1] All the Inteſtines tranſmit their Blood to the Vena Portæ, except only the Rectum, which but in part ſends its Blood to the Liver by the internal Hæmorrhoidals, and partly to the Cava by the external Hæmorrhoidal Veins.

[2] For ſince the Fæces of the Inteſtines are putrified chiefly in the Colon and Rectum, their fætid and rank Vapours will be continually taken up by the Veins which are there ſeated, being partly abſorbed, and partly penetrating by their own ſubtle Nature; and this volatile alcaline Vapour ſeems to be a neceſſary Ingredient towards the Formation of the Bile.

§. 336. Finally, all the Blood which was conveyed to the Meſentery and Inteſtines by the upper and lower meſenteric Arteries, having there performed its Office, returns through the *meſenteric* [1] Veins, and at length mixes with all theſe returning Humours before they enter the Liver. But this laſt Blood from the Inteſtines and Meſentery, has been alſo in a great meaſure deprived of its Lymph, (§. 91.) ſome of which forms the inteſtinal Juice, and being partly perhaps repleniſhed with the more ſubtle Parts of the Chyle, (§. 106.) it furniſhes proper Matter for the Formation of the Bile. But there is alſo a large Portion of this arterial Blood ſent to the Meſentery and Inteſtines, which is carried back by other Veins of a diſtinct Order, diſperſed through the Membranes of the Inteſtines and Meſentery; and theſe Veins do not open into the large meſenteric Vein, and therefore they do not carry their Blood to the Vena Portæ, but to the Vena Cava. But then the Origin, Courſe, Ramification and Termination of theſe Veins is very different from the meſeraic Veins which paſs to the Vena Portæ: for every Viſcus has Veins returning the Humours which are ſuperfluous after the Nutrition is performed, and other Veins which return that Blood which is brought to each Viſcus for its publick Action or Uſe.

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[1] All Anatomiſts generally agree, that there is no other Way for the Blood to return from the Inteſtines. But in the Year 1720, I received Letters from *Ruyſch*, in which he candidly communicates, that he had filled the Vena Cava at a ſmall

Diſtance from the Liver with ceraceous Injection, and after tying it above and below, he found a great Number of its venal Branches appearing throughout the Meſentery and whole Tract of the Inteſtines. But theſe Veins appear to be diſtinct from thoſe Branches which belong to the Porta, as was demonſtrated by injecting the Vena Cava and Vena Porta ſeparately in the ſame Subject. And he obſerves, that the Nature and Diſtribution of theſe two venal Syſtems and their Branches, are ſurprizingly different. Thus therefore there ſeems to be a twofold Circulation of the Blood in the Meſentery and Inteſtines, one commonly known, in which the Blood brought by the cæliac and meſenteric Arteries, (deprived of its mucous and ſalival Juices which diſtil into the Cavity of the Inteſtines, and inſtead of that repleniſhed with the more ſubtle Parts of the Aliments, Bile, and inteſtinal Juices,) returns back by the Vena Porta to the Liver. For that there is an Abſorption of the Bile (§. 106.) we are fully perſuaded, 1. Becauſe the Chyle which mixes in the Inteſtines with a very bitter yellow Bile from the Gall-bladder, is nevertheleſs white and ſweet in the lacteal Veſſels, and therefore it muſt neceſſarily have depoſited all or the greateſt Part of the Bile which it had before received. 2. From the peculiar Nature or Condition of the Blood returning by the meſenteric Veins, which appears of a dark yellow, very fluid and different from any Blood found in other Parts of the Body; which Difference ſeems to ariſe from the Bile, ſince a Bitterneſs has been ſeveral times taſted in it by various Anatomiſts. 3. From the Effects of the acidulæ purging Waters, which ſooner remove Obſtructions of the Liver than of any of the other Viſcera. But there is beſides this another Circulation of the Blood in the Meſentery, by the

Veins which return the redundant Blood after the Office of Nutrition into the Cava, as *Ruyſch* lately diſcovered; and I am in no ſmall Hopes but that there may be alſo correſponding Arteries diſcovered by injecting the Aorta, ſo as to fill it very exactly with ceraceous Matter, after tying the meſenteric Arteries.

§. 337. The Blood therefore which flows immediately through the Vena Portæ into the Liver, is very *fluid* [1], highly attenuated, diluted with Lymph and repleniſhed with the old returning Humours, eſpecially the Spirits and Bile; and thus theſe ſeveral Humours, very different from each other, and returning from different Quarters, are intimately mixed in the large Sinus or venal Trunk where they concur; and this Mixture is rendered more perfect, partly by the Force of Reſpiration which acts powerfully upon theſe Parts, (§. 86.) and partly by the Impulſe of the Blood itſelf, by which means it is rendered fit for Secretion, and capable of paſſing on afterwards into the Veins.

[1] The principal Deſign of Nature in placing the Omentum and Spleen under the Preſſure of the Diaphragm, ſeems to have been to forward the venal Blood in the Branches which tend to the Porta; for otherwiſe it would paſs on with too weak a Motion which it received only from the Arteries deſtitute of the Force of the Heart: whence this ſluggiſh Blood deſtined to paſs through a ſort of converging Arteries, is by this Motion continually excited to circulate and overcome the Impediments which might otherwiſe cauſe it to ſtagnate. From

all theſe Phænomena we learn that the Blood of the Vena Portæ is very fluid, ſcarce congealable, and not very red; whence it is well adapted to be diſtributed through all the ſmaller Veſſels of the Liver without Danger of cauſing Obſtructions; all which is further promoted by the alternate Preſſure communicated in Reſpiration, by which the Lymph and thinner Humours from the Inteſtines and Spleen, are alſo blended with the other Parts of the Blood.

* * *

Of the Action of the LIVER.

§. 338. THE Vena Porta therefore being compoſed of ſo many Veins, converging together into one Trunk, riſing upwards, it enters the *Liver* [1] about the middle of its concave Surface, betwixt the Tubercles or Protuberances which are called (πυλαι) *Gates* [2], and ſoon after acquiring a firm and ſtrong fibrous Coat or *Capſule* [3] like the Tunics of the Arteries, it forms a large *Sinus* [4] for about the Space of half an Inch, in which the ſeveral Humours being impelled, collected, *mixed* [5], and retarded in their Courſe, are further divided by the Motion and Action of *Reſpiration* [6], ſo as to be intimately mixed, and afterwards more equally diſtributed throughout the Liver.

[1] The Liver is a Part wanting in no Animals, as far as we can diſcover, and is generally larger in proportion as the other Viſcera are leſs, as we

ſee in Fiſh and Inſects. In Fiſh there is no Thorax, but a very large Abdomen, which is moſtly filled with the Liver, Pancreas, and a few Inteſtines, as I have obſerved in the old Wife-Fiſh; and in the Canis Carcarius, which weighed three thouſand Pounds, there was almoſt one ſixth Part of it Liver, from whence it is evident that this Viſcus is of the laſt Neceſſity to Life.

[2] This Paſſage has derived the Name of Gates from the Similitude of a Way paſſing between two Hills, which the *Greeks* called *Pylas*, as *Thermophelas*, &c. and it is from that Valley through which the large Vein of the Liver paſſes, that it has derived the Name (φλεψ πυλῶν) *Vena Portarum*, from whence the common Name Vena Porta is improperly derived.

[3] Such a Strength was altogether neceſſary in the Veins of the Liver; for as the Blood is there to paſs from a large Trunk into narrow Branches, and this with little or no Aſſiſtance from the Contraction of the Heart, through a Veſſel which does not propel its Contents by the Elaſticity of its Coats; therefore the Blood would never have been able to overcome the Reſiſtances of the ſmalleſt Veſſels which it paſſes, if the common Sinus was not contracted by a muſcular Membrane, which forwards the Blood into the Liver.

[4] The Vena Porta is expanded into a large Sinus, in the ſame manner as the Vena Cava is diluted into the right Sinus of the Heart. Nor is this the only Similitude, ſince the Sinus of the Vena Porta is as much a Heart to the Liver, as the Heart, properly ſo called, is to the whole Body: for all the venal Blood is here received in its Paſſage to the Liver, and then the thin Vein of the Porta is inveſted with a ſtrong fleſhy Integument, which was firſt deſcried in the Liver by *Gliſſon*,

who has denominated it a Capſule: whence it has been called the *Capſula Gliſſonii.* Nor ſhall we be liable to any Exception, if we call this Cavity of the Liver by the Name of the venous Sinus.

[5] If the Veins which unite into the large Trunk of the Porta, to wit, the ſplenic, epiploic, gaſtric and meſenteric, went each of them diſtinctly or ſeparately to the Liver; then only one Portion of this Viſcus would have received the oily Part of the Blood, another Portion would have received the watery or thin Blood of the Spleen, while the acrid inteſtinal Blood would have been carried to ſtill a different Part of the Liver; and therefore the Bile, which requires a Mixture of all thoſe Humours, could not have been formed.

[6] The Force of which is not inconſiderable; for the Liver is ſuſpended to the Diaphragm by a large and ſtrong Ligament, and therefore the Liver follows the Agitation of the Diaphragm every time it moves in Reſpiration.

§. 339. But immediately after the Porta loſes the Nature of a *Vein* [1] and Sinus, it divides into five large Branches, which are diſtributed into an infinite Number of others, which are ſtill ſmaller, and diſpoſed throughout almoſt every Point of the Liver, in ſuch a manner that they at laſt eſcape the Sight, and compoſe the *principal* [2] Part of the Subſtance of this Viſcus.

[1] We here meet with a ſurpriſing Alteration, not to be parallel'd in any other Part of the Body, namely, the Converſion of a Vein into an Artery. The Vena Portæ is truly a Vein, till it is arrived near its Entrance into the Liver; but after paſſing

through the Gates or Entrance betwixt the ſmall Lobes of the Liver, it then becomes truly an Artery, without being firſt extended either to the Heart or Lungs. For, in the firſt place, it is covered with a muſcular Coat, which always accompanies the Arteries, but is never found in the Veins. But yet there is ſome Difference in this Coat from the common Fabrick of that in an Artery; for every Artery puts off all that is muſcular in its Tunics, ſo ſoon as it has reached any Viſcus: but, on the contrary, the Vena Portæ, which was before thin, acquires a muſcular Coat in its entering the Liver. (2.) Beſides this, it is uſual for Arteries to divide themſelves into ſmaller Branches, as it is for Veins to ariſe by ſmall Beginnings, and to terminate or run together in larger Trunks, 'till they reach the Heart, without making new Diviſions. But the Vena Porta divides itſelf a ſecond time into Branches extended from its common Trunk. (3.) The Courſe of the Blood in Arteries is from the Heart into the ſmaller Extremities of the Veſſels, and ſuch is the Courſe of it through the Porta in the Liver. (4.) The Bile is ſecerned from the Vena Portæ, whereas Secretion is the Buſineſs of an Artery. (5.) Laſtly, Every Artery is furniſhed with a correſponding Vein, which returns the Blood in a contrary Direction towards the Heart, from whence it was brought by the Artery: but all this is truly the Caſe with reſpect to the Vena Portæ, which returns the ſuperfluous Blood after the Secretion is formed through the hepatic Veins into the Cava. The Vena Portæ therefore has all the Properties of an Artery; ſo that it is from hence apparent, that the Ancients had ſome Reaſon for making two Sources of the Veins, the one from the Heart, and the other from the Liver.

[2] I keep by me a human Liver, which was happily filled with Injection through the Vena Portæ by *Ruyſch*. If a Bit of this Viſcus, which has been varniſhed with Oil of Turpentine, be viewed with a Microſcope in the Sun's Rays, (without which it will not be ſufficiently viſible) there will then appear an infinite Number of ſmall Veſſels throughout the whole Particle, which is itſelf no bigger than a Grain of Sand; inſomuch that you would be ready to ſwear, that the whole Subſtance of the Liver was compoſed merely of Branches from the Porta. The ſame Appearance of Veſſels may be alſo diſcerned by taking off the external Membrane from the Liver, ſhaking and diſſolving a ſmall Particle of it in Water. Theſe Veſſels therefore we may, for the ſake of Diſtinction, reaſonably call the Arteries of the Sinus of the Vena Portæ.

§. 340. In the next place, the hepatic *Artery* [1] ariſing from the left Branch of the cœliac, enters the Liver near its Gates or Protuberances before-mentioned: and inſinuating itſelf in the acquired Subſtance of the Capſule, it is diſtributed therein, and ramified throughout every Part of the Liver, inſomuch that there is not the ſmalleſt Point without ſome Branch of it; and thus it not only ſpends itſelf upon the Capſule or Coats of the Porta in the Liver, but alſo ramifies itſelf through every Part; only as it does not ſtand in need of this Capſule, it does not ſo cloſely inveſt or penetrate the ſame in the larger Veſſels. Beſides the hepatic Artery, there are two others extended from the Diaphragm and ſuſpenſory Ligaments, and inſerting their Branches together with the former, they are at laſt joined by other ſmall Branches which come from the cyſtic Arteries themſelves.

[1] This Artery extends itſelf throughout every Part of the Liver, in which the Branches of the Porta are diſtributed, even into the minuteſt Penicilli or Bunches of the Vaſcules; in which it is conſpicuous, whenever the Arteries and Veins have been filled with Injection of different Colours. I keep by me ſome Livers injected by *Ruyſch*, which ſeem to be in a manner compoſed of nothing elſe but the hepatic Arteries. But if the Vena Portæ only is injected, it will quite compreſs and obſcure the hepatic Arteries. Theſe Arteries appear to the beſt Advantage when they are firſt injected, after the Blood has been waſhed clean out of all the Branches of the Vena Portæ, by the repeated Injection of warm Water. *Gliſſon* has obſerved, that theſe Arteries do not penetrate the Capſule which bears his Name, but that it creeps on the Surface of that Capſule.

§. 341. But the Vena Cava tending upwards towards the Diaphragm, and inſinuating itſelf into the gibbous Part of its Surface, does there receive three large *Branches* [1] coming from the Liver, which are inſerted by diſtinct Apertures, and it alſo receives ſeveral ſmaller Branches; all which being compoſed of numberleſs minute Twigs diſperſed through the *whole Subſtance* [2] of the Liver, do at length return into the Cava all the Blood which was conveyed to the Liver by the Vena Portæ; though thoſe Branches of the Cava ſeem to be *leſs* [3] both in Number and Size than thoſe of the Porta.

[1] In that Part where the Veins which come from the Liver into the Cava are inſerted, we meet with a peculiar Sort of Pellicle, which is in effect a true Valve, moveable, and ariſing from the right Angle, which the large hepatic Vein forms with the Trunk of the Vena Portæ, being rightly deſcribed by nobody but *Winſlow*. This moveable or fluctuating Membrane admits the Blood returning from the Liver to enter into the Cava, but prevents the Blood of the laſt from returning back towards the Liver in violent Motions of the Body, when the Courſe of the Blood is accelerated through the iliac Veins towards the Heart, and by its Impetus might otherwiſe enter the Liver latterly: but thus it cloſes the Mouths of the hepatic Veins, as it is inclined by the Weight or Impulſe of the Blood, which is by this means prevented from returning out of the Cava into the hepatic Veins. Immediately above this Valve the Cava paſſes through the tendinous Circle of the Diaphragm, and immediately forms the Sinus of the right Auricle: for in the human Body there is no inferior Trunk of the Vena Cava in the Thorax as the Ancients imagined, the Truth of which is expreſſed with faithful Figures by *Euſtachius*.

[2] Wherever a Branch of the Vena Portæ terminates, there a ſmall Twig or Circle of thoſe Veins ariſe which belong to the Cava; nor is there ſo much as a ſingle Grain of the Liver, in which there are not the Extremities both of the hepatic Artery, the Vena Portæ, together with the incipient Branches of the Vena Cava. I have ſome Livers by me filled by *Ruyſch* with ceraceous Injection through the Vena Cava, which is indeed not very difficult

to perform after the Valve has been perforated with a Probe; and this way the Liver ſeems to be entirely compoſed of Branches of the Vena Cava. For when theſe only are filled, all the other Veſſels are compreſſed into a very ſmall Subſtance; inſomuch that from hence aroſe that Diverſity of Opinions among former Anatomiſts, ſome of whom affirmed the Liver to be compoſed only of the Veins of the Porta, and others only of the Cava; but the Ancients deſtined the gibbous Part of the Liver to be the Seat of the Vena Cava, and aſcribed the concave Part to the Trunk of the Porta.

[3] This has been truly demonſtrated by *Ruyſch*, in Oppoſition to *Gliſſon* and *Malpighi*: for after the Bile has been ſecerned, the Humours which are returned by the hepatic Veins to the Cava muſt be proportionably leſs.

§. 342. Wherever the *Extremities* [1] of theſe two laſt mentioned Veins (§. 339, 341.) are joined together, they become ſo extremely minute as to form ſurprizing fine Penicilli or little Bunches like Pencil Bruſhes diſpoſed in Bundles, and theſe again are diſpoſed ſo as to appear like little diſtinct *Globes* [2] formed of the almoſt inviſible Vaſcules diſtinguiſhed one from the other: but theſe globular Corpuſcles or Bundles of the Penicilli very much reſemble the Bodies which we call ſimple Glands; and theſe are collected together into little Lobes which unite again into larger Lobes, 'till they at length make up the whole Subſtance of the Liver. And that this is the Fabric of the Liver we are aſſured by the Inſpection of it in Inſects, Fiſh, Quadrupeds, and Birds, with the Formation of the Liver in theſe Animals before Birth; as alſo from the Diſeaſes of the Viſcus itſelf, and from what is manifeſted in it to the naked Eye by anatomical Injections.

[1] Throughout the whole Subſtance of the Liver there is no Fat obſerved, notwithſtanding the cellular Membrane is there found, extending itſelf within the Capſula *Gliſſonii*; and by making a ſmall Wound it may be ſo inflated that the Air will paſs betwixt the Capſule and the Vena Portæ, ſo as to follow all the Ramifications of the latter. I formerly urged in Oppoſition to *Ruyſch*, that the Caſe of Hydatides ſeemed as an Argument to prove that the Liver was compoſed of Glands, inaſmuch as the whole Liver had been ſeveral Times found by Anatomiſts compoſed almoſt entirely of watery Veſicles: to which *Ruyſch* anſwered, that the cellular Membrane penetrated betwixt the Capſula *Gliſſonii* and Veins of the Porta throughout the whole Subſtance of the Liver, which he had ſometimes ſeen to contain Fat; and that therefore this Membrane might be ſo changed in a Dropſy, that the Veſſels being compreſſed by the confined Water might in a manner diſappear, and render the whole Viſcus apparently a mere Aſſemblage of Veſicles. And he affirms, that beſides this ſpungy or cellular Texture, he could find nothing in the whole Subſtance of the Liver but mere Bundles of Veſſels.

[2] The Liver of a Hog nearly reſembles that of a human Body; and this, as alſo the human Liver itſelf, being diligently inſpected, has in its external Surface the Appearance of innumerable and ſcarce viſible little Grains, which *Malpighi* took to be ſimple Glands. But *Ruyſch*, by exquiſitely filling the Vena Porta in human Livers, could find

nothing in theſe Grains but Penicilli, or Bunches compoſed of thouſands of the ſmalleſt Vaſcules, which lying by the Side of each other, reſemble the Appearance of the many fine Hairs in a Pencil Bruſh. He alſo found that theſe Grains, or ſeemingly ſimple Glandules, ſeparated by Maceration and ſhaking in warm Water into minute Penicilli of this kind; and adds, that he perceived in the Penicilli the ultimate and moſt minute Threads both of the Vena Porta, the Vena Cava, the hepatic Arteries, and the biliary Ducts. I have by me a Liver prepared with great Artifice, in which the biliary Ducts are injected with Wax; but the whole Liver looks red, and there is apparently a ſmall Branch of the biliary Duct, with a ſmall Artery and Branch of each Kind of the Veins aſſembled together in each of theſe Grains or Corpuſcles, which are compoſed of the Penicilli. There has been a long Controverſy betwixt me and *Ruyſch* with regard to the Queſtion, Whether the Liver is compoſed of Follicles or ſmall Glandules, or elſe of mere Bunches of Veſſels, without being wrapped up in diſtinct Membranes? The former of which Opinions I defended: which was alſo the Opinion of *Ruyſch* himſelf, until he afterwards changed his Mind.

§. 343. About all the forementioned glandular Corpuſcles, or Bunches of ſmalleſt Veſſels, (§. 342.) there appear *ſmall Ducts* [1] ariſing by an inviſible Origin from thoſe ſmalleſt Penicilli, or Bunches of Vaſcules (§. 342.): and theſe Ducts always accompany the Ramifications of the Porta, being inveſted in the ſame Capſule, to which they ſo firmly adhere, as to be ſcarcely ſeparable; theſe ſmaller Ducts gradually uniting together into larger of the ſame Kind, do at laſt end in one great *Tube* [2] at the Trunk of the Vena Portæ, which Tube or Canal is called the Porus Hepaticus, the hepatic or biliary Duct, into which Duct a Humour very different from the Blood is received, and afterwards diſcharged under the Denomination of the *hepatic Bile* [3] (§. 340.)

[1] In every ſenſible Point of the Liver, there is a Conjunction of three diſtinct Veſſels, namely, a ſmall Branch of the Vena Cava communicates with the correſponding ſmall Branch of the Vena Porta, and betwixt the Union or Anaſtomoſes of theſe Veſſels ariſe ſmall Ducts of the Liver, whoſe Branches unite together, and all the way accompany the Branches of the Vena Portæ, as *Gliſſon* has long ago obſerved: for by injecting Ink into the biliary Duct, he traced the Courſe of the Veſſels from the Porta through all Parts of the Liver. But the Origin or Riſe of this ſecretory Duct from the meeting of the two Veins, ſeems to be much after the nature of the ſmalleſt Follicles (§. 242.) into whoſe Cavity the Bile is ſeparated from Arteriolæ aſſembled together in the Form of a Pencil Bruſh; from whence the Bile is conveyed by a ſmall Radicle of the Ductus Hepaticus, by an Aſſemblage of which Radicles, collected into one large Trunk, is formed the Ductus or Porus Hepaticus. For it does not ſeem reaſonable that the Bile ſhould paſs immediately from the Arteries into the Veins; ſince this is oppoſed by the Inſtance of the Urine (§. 352.), which is diſtilled through the urinary Ducts, collected together into about twelve pyramidal Bundles, a thouſand of which are found opening in every Papilla, which diſ-

charge the Urine into the laſt Follicle or Pelvis of the Kidney. But this is not all; for there is a ſecond Emiſſary, the Ureter, which receives the Urine from the Pelvis, and conveys it into the general Follicle belonging to both Kidneys, namely, the Bladder; from whence it is at length diſcharged out of the Body by the Urethra, which makes a third Emiſſary.

[2] This is collected in the Sinus of the Porta, and is compoſed of five principal Branches, but yet it does not follow the large Vein of the Porta, but runs in a direct Courſe to the Duodenum: and this is the excretory Duct of the Liver, which is ſingle and diſcharges the Bile ſeparated by the Fabric of the Liver. But the Lymph and Blood which remain ſuperfluous after the Buſineſs of Nutrition, are returned by the Vena Cava, and the Lymphatics to the thoracic Duct, and are in nothing different from the Blood and Lymph of any other Viſcus.

[3] Which is mild, ſweet and watery; (§. 98.) for it is ſecerned in the Liver, of a very mild Taſte in all Kinds of Animals.

§. 344. Conſidering the *Fabric* [1] of the Vena Portæ (§. 338.) and Vena Cava (§. 341.) with the Pori Hepatici (§. 343.) it will appear from thence, and from conſidering the Motion of the Humours propelled through the Vena Portæ, (§. 337.) with the Nature of the Juice contained in the Pori Biliarii, and from anatomical Experiments made by *tying* [2] and *dividing* [3] the Duct ſo as to collect the Bile, I ſay it will from all theſe Particulars appear, that a *Juice* [4] is ſeparated from the Blood of the *Vena Portæ* [5] in the ſmalleſt Extremities of that Veſſel, which is conveyed ſoon after by the Branches of the Pori Biliarii through one large Canal out of the Liver; while the Blood remaining after the Secretion returns by the Branches of the Cava from the Liver *towards the Heart*[6].

[1] So that the extreme Branches of the Vena Portæ terminate either in glandular Follicles, or in vaſcular Penicilli. (§. 342.)

[2] If the Vena Porta is conſtringed with a Ligature in a living Dog, the Secretion of the Bile will by that means be totally ſuppreſſed in a few Hours time. But if the Ductus Hepaticus be conſtringed with a Ligature out of the Liver, a Tumor is then formed betwixt the Liver and the Ligature, while the Duct remains empty and collapſed, betwixt the Ligature and the Inteſtine.

[3] If the hepatic Duct is divided in a living Animal, the whole Cavity of the Abdomen will in a little Time be filled with extravaſated Bile from the Liver.

[4] Not derived from the Vena Cava as many of the Ancients ſuppoſed; for the Valve or Membrane mentioned (§. 341.) is an Obſtacle which permits the Blood to return from the Liver into the Cava, but prevents it from paſſing from the Cava into the Liver. This Valve or Membrane has been formerly delineated by *Euſtachius* and *Veſalius*.

[5] In great plenty, as is evident from the large Bulk of the Liver, and Capacity or Diameters of the Branches of the Vena Portæ, as alſo from the Calculations of *Borelli*, and from the Experiments of *Nucke.* This laſt Anatomiſt opened the Abdomen of a living Dog, extracted the Duodenum, and made a Ligature upon the hepatic Duct, at a

ſmall Diſtance from the Inteſtine; beyond the Ligature he inſerted a Quill into the Duct, which he faſtened by proper Ligatures, ſo as to come out of the Abdomen, while all the other Viſcera were retained in their proper Places. Thus he made a continual Diſcharge of the hepatic Bile, which he collected to the Value of ſeveral Ounces in a few Hours time. There is certainly nothing more uſeful and entertaining than Experiments made on living Brutes, which inclined me to be frequently preſent at the Experiments of *Nucke*; in which Branch of Knowledge I ſhould certainly have ſpent more Time, if other Buſineſs had permitted.

[6] Namely, the Blood of the Vena Portæ which returns to the Heart. For the Liquors injected by that Vein return through the Cava; but the hepatic Artery being injected does not fill the Vena Cava, which Artery ſeems to have thoſe Branches of the Vena Azygos for its fellow, whoſe Branches *Euſtachius* diſcovered paſſing to the Liver. But the Paſſage of the Blood from the Porta into the Cava is alſo demonſtrated by a Ligature, made upon the Vena Cava at the Diaphragm, whereupon the Liver becomes ſo turgid as to almoſt burſt in the middle.

§. 345. While Secretion of this Viſcus is alſo rendred ſtill more evident from the Diſtribution of the hepatic *Nerve* [1], which, like the Artery, ramifies and accompanies the Vena Portæ throughout all its Diviſions.

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[1] Which Nerves coming from the eighth Pair, and from the Intercoſtal, are divided ſo as to accompany the Capſula muſculoſa *Gliſſonii* throughout every Point of the Liver, and ſeem as it were to animate this muſcular Fabrick, that the Blood

which here receives little or no Force from the Heart, nor yet from the Arteries, might be capable of paſſing through the converging Veſſels of the Liver. Which Nerves alſo, beſides their Neceſſity for all muſcular Action, ſeem to diſcharge ſome of their Juice, as well in the Liver as in the other Viſcera.

§. 346. Now in the *human Liver* [1] there is a ſmall oval Bladder *fixed* [2] in its concave Part, for receiving the Bile; which Bladder, being compoſed of an infinite Number of Veſſels of all kinds interwoven, is pretty capacious, and terminates in a ſpiral or *contorted Duct* [3] wrinkled on the Inſide, which is called the cyſtic Duct, ſituated in ſuch a manner, that its Neck and narrow Part lies *higher* [3] than the bottom of the Cyſt; which Neck being continued to the Porus hepaticus, which it meets in an *acute Angle* [5], they both together unite, and form one common Duct, larger than either the hepatic or cyſtic Duct alone; which common Duct deſcending, enters the external Coat of the Duodenum at an acute Angle; and after deſcending a little way betwixt the external and the next Coat, it ſoon perforates the ſecond, and paſſes a conſiderable way betwixt that and the third Tunic; after which, it opens freely by a round Aperture into the Cavity of the Inteſtine; from whence we learn, that the Bile can be diſcharged this way into the Inteſtine, *not at all times* [6], or under alll Circumſtances, but only when the Inteſtine is relaxed, but not at all when its Coats are *ſtrongly contracted* 7.

[1] Animals which are exerciſed with hard running, ſuch as the Dromedary-Horſe, Stag, Range-Deer, and many of the Fiſh kind, have no Gall-Bladder, but inſtead of that, they have various Ducts diſpoſed in an extraordinary manner. In other Animals again, there is a Gall-bladder, but placed at a Diſtance from the Liver, as in the Cat, Tiger, *&c.*

[2] In ſuch a manner, that a large Part of the Gall-bladder, even almoſt the half, is buried in the Subſtance of the Liver. But its Poſture is ſuch, that in erect People the bottom is lowermoſt, at which time nothing can paſs out of the Gall-bladder unleſs it was quite full. It is alſo covered with the common Membrane of the Liver, which is continued from the Peritonæum, being very thin, and full of ſmall Veſſels. The other Membrane of it is thicker, and in a manner muſcular; but yet it does not ſeem to have any ſuch Action of corrugating, like that of the urinary Bladder, ſince half of the Veſicula Fellis is firmly attached to the Liver; and therefore its chief Uſe ſeems only to be for preventing too great a Dilatation of this Receptacle. There are an infinite Number of Blood-veſſels in its Texture, and the Arteries are diſpoſed in a peculiar manner, ſo as to induce one to imagine that they muſt have ſome particular Uſe more than common. Its Capacity is uſually about two Ounces; but in acute inflammatory Diſeaſes, it is ſurprizingly diſtended, as was obſerved in the epidemic Fever of the Year 1727: and in theſe Caſes it has been found to contain ſix or eight Ounces.

[3] This ſpiral Valve has been well obſerved by *Nucke*, and his Pupil *Reverhorſt.* This Valve

prevents the Bile from paſſing eaſily either into or out of the Veſicula Fellis; ſo that it is retained in the Gall-bladder, 'till ſome additional Preſſure aſſiſts to overcome the Reſiſtance of the Valve. But both the cyſtic and common Duct paſs under a Membrane, which is continued from the Gall-bladder to the Duodenum.

[4] For People generally either ſit or ſtand erect, and in that Poſture the Neck of the Gall-bladder will be uppermoſt: but in a ſupine Poſture it will be lowermoſt; from whence it is evident, that the Bile will be ſometimes retained, and ſometime expelled alternately.

[5] From hence it happens that nothing can paſs out of the hepatic into the cyſtic Duct, unleſs the Bile meets with a greater Reſiſtance in the common Duct than that which ariſes from the Angle of the cyſtic Duct; and, on the contrary, that nothing can paſs out of the Gall-bladder towards the Liver, unleſs the common Duct gives a greater Reſiſtance than that which ariſes from the Angle of the hepatic Duct. Therefore for the Bile to paſs out of the Gall-bladder either to or from the Liver, ſuppoſes ſome additional Force more than natural, and has occaſioned ſome to imagine that neither the Bladder had its Bile from the Liver, nor that the Liver received any from the Gall-bladder; ſince if this had been the Intention of Nature, ſhe would have conjoined the two Ducts at right Angles. Wonderful Diſputes have aroſe concerning this Motion of the Bile, eſpecially about the Time when *Helmont* and *Sylvius* publiſhed their Writings upon this Subject. But the Generality, with *Gliſſon*, will have the Courſe of the Bile to be from the hepatic Duct into the Gall-bladder: To which it is objected, that if this had been the Deſign of Nature, ſhe would have made

the Courſe more open betwixt the two Ducts. But whatever was the Deſign of their Conjunction, it was evidently to produce a Mixture of the cyſtic and hepatic Bile in the common Duct.

[6] In Men the Gall-bladder is never obſerved to be full, unleſs in a diſeaſed State; but it is ſo far empty, that it will uſually hold about a third Part more of any Liquor. But after long faſting this Receptacle becomes very turgid in all Animals. I once ſaw the Gall-bladder thus diſtended in a fat Hog, which had not been fed for three Days, and the Neck was ſo much contracted by the Diſtention of the Coats, as not to allow one Drop to be expreſſed.

[7] Nothing can paſs into the common Duct from the Inteſtine, ſince nothing can be applied within the Inteſtine to dilate the Mouth of this Duct, but what will at the ſame time obſtruct it more powerfully, as it endeavours to dilate it more violently. But neither can the common Duct of the Bile diſcharge it ſelf under all Circumſtances; for when the Inteſtine is violently contracted with a convulſive Force, it affords no Admittance to the Bile: and it equally denies a Paſſage to the Bile by ſhutting up the Mouth of the common Duct, when the Inteſtine is too much diſtended by a Flatus; from both which Cauſes, the Bile may be forced to return back into the Liver and into the Cyſt in a different manner to what is uſual in the natural or healthy State of the Parts. An Obſtruction of the Bile, and its Conſequences, have been obſerved, as well from a Diſtention of the Inteſtines as from Poiſons; by the Action of which laſt, the Stomach has been diſtended with Wind like a pair of Bellows: And this was the Caſe alſo in the epidemic Fever lately mentioned, in which no Wind could

be diſcharged; from which Cauſes a Jaundice may ſoon follow in various Degrees.

§. 347. From an *hydraulic* [1] Conſideration of this Fabric of the Liver (§. 346.) compared with what was ſaid before (§. 344.), it will very evidently appear, that a Humour is conveyed from every Point of the Liver and Gall-bladder through the common Duct, into that Part of the Inteſtine, by a natural Aperture, where the Chyle is moſt retarded for the firſt time, after it has been expelled from the Stomach: And this is ſtill more evident, becauſe when the Gall-bladder has been ſometimes found *abſent* [2], its Place has been ſupplied with many ſmall biliary Receptacles, formed of an Aſſemblage of the biliary Ducts, ſo as to diſcharge the Bile into the Duodenum by many ſmalls Canals.

[1] Namely the Vena Portæ carries the Blood into the Liver, where it depoſits the biliary Juice through the Ducts of the Veſſels which form the Penicilli, into the Cavity of their Follicles; but from theſe Follicles the Bile is received into the Pori or Ducts, whoſe Numbers are infinite; but are all of them at length collected into one common Duct, which receives alſo the cyſtic Bile, and mixing together with that from the Liver, conveys the mixed Bile into the Duodenum. This is the general Courſe of Nature; but the other Courſes which the Bile ſometimes takes, are preternatural.

[2] There have been many cyſtic Ducts obſerved, which did not open into the hepatic, but inſerted themſelves ſeparately into the Duodenum; in

which Caſes the Bile certainly never paſſed from the hepatic into the cyſtic Duct.

§. 348. We are in the mean time taught by Experiments, that there is an open and eaſy Paſſage from the Cavity of the Gall-bladder into the Liver, the common Duct, and into the Cavity of the *Inteſtine*[1], as alſo from the *Liver*[2] by the Ductus Hepaticus into the *cyſtic Ducts*[3] and the Bladder itſelf, as well as into the Inteſtines; and laſtly, that there is a like Paſſage from the hepatic into the cyſtic Duct, and from the cyſtic into the hepatic. Comparative Anatomy alſo informs us, that in ſome Animals the Gall-bladder is wanting, as in Horſes; and in others, that the hepatic Duct diſcharges its *Humour*[4] into the bottom of the Gall-bladder: We alſo know, that the hepatic Bile is plainly *different*[5] from that contained in the Gall-bladder (§. 98.) From all which it appears that the hepatic Bile (1.) tends naturally *downwards*[6], (2.) *ſometimes*[7] into the Gall-bladder; (3.) ſometimes alſo being preſſed back *into the Liver*[8], it enters the Vena Cava, and flows all over the Body; (4.) that by ſtagnating in the Gall-bladder, it *acquires*[9] the Properties of cyſtic Bile; (5.) that perhaps a Portion of the bittereſt Part of the cyſtic Bile may ariſe from the ſmall *Glands*[10], ſeated in the Membranes of the Gall-bladder, and ſupplied by the cyſtic Arteries, in the ſame manner as in the Membrane which lines the auditory Paſſage; (6.) that this *mixes*[11] with the hepatic Bile flowing into the Gall-bladder itſelf.

[1] If all the biliary Veſſels remain in their natural State, and a Preſſure is made either upon the cyſtic or hepatic Duct, the cyſtic or hepatic Bile will then conſtantly flow into the Duodenum; and if either of the aforementioned Ducts are tied with a Ligature, they will appear turgid betwixt the Ligature and the Liver or Gall-bladder, but quite empty betwixt the Ligature and the Duodenum.

[2] If the common Duct of the Bile is tied, and Urine or Water is injected into the Gall-bladder, after it has been firſt tinged with ſome Colour, that Water or Urine will flow into the Liver thro' the hepatic Ducts. This Courſe is not natural, but only that which the Bile takes, when the Reſiſtance at the common Duct is greater than towards the Liver.

[3] If the common Duct be tied, and a Preſſure made upon the hepatic Duct, the Bile will then run into the Ductus cyſticus and Gall-bladder, ſo as to fill the latter till it is almoſt ready to burſt.

[4] In ſuch a manner that the hepatic Duct is not connected with the cyſtic, but inſerted into the bottom of the Gall-bladder.

[5] We have frequently obſerved before, that the hepatic Bile is mild, and that of the cyſt very acrid, as conſiſting of a rancid Oil render'd extremely bitter; and therefore there is a conſiderable Difference betwixt the cyſtic and hepatic Bile (§. 98.)

[6] All the excretory Ducts in the human Body obſerve this general Rule, namely to convey their Juices from a larger to a ſmaller Capacity, unleſs ſome particular Obſtacles ſhould intervene. If therefore we compare the common Duct with the hepatic and cyſtic, we ſhall find the former leſs

than the two latter; beſides which Difference in the Capacity of the Ducts, there is little elſe that can determine the Courſe of the Humour that way from the Gall-bladder upon the Addition of any Preſſure. It therefore remains as a general Rule, that the Bile muſt flow from the ſmaller hepatic Ducts into the larger, and from thence into the Cavity of the Inteſtines.

[7] I cannot indeed conform to the Opinion of *Gliſſon* and *Raw*, who ſuppoſed all the hepatic Bile was firſt poured into the Gall-bladder: but I only aſſert that the hepatic Bile flows back into the cyſtic Duct, whenever there is an Obſtacle or Reſiſtance made in the common Duct, whether that Obſtacle proceeds from a Calculus, Flatus, a ſpaſmodic Conſtriction of the Inteſtine, from an Acid, Inflammation, or any other Cauſe obſtructing the Courſe of the Bile into the Duodenum; and that the Gall-bladder is filled under theſe Circumſtances is evident to the Eye, by making a Ligature upon the common Duct in a living Dog. In general, there is a free Communication betwixt the Gall-bladder and any other Part of the Liver; as alſo betwixt every Part of the Liver and the Gall-bladder; ſo that the Bile may paſs either from one to the other either way, according as one Courſe may be more eaſy than the other.

[8] It appears from Experiment, that by injecting a Liquor through the common Duct, it enters the hepatic Duct, the Gall-bladder, the whole Liver, and even it fills the Vena Cava itſelf. This is confirmed by innumerable Obſervations. In every new born Infant a Jaundice follows ſooner or later, and the inteſtinal Fæces are diſcharged white and like Cheeſe, while the Skin itſelf is tinged with a yellow Colour: If now *Syr. de chicoreo cum rheo* be exhibited, or *Venice* Soap given from five Grains

to half a Dram with *Lap. Cancrorum*, the Skin will then by degrees whiten, the Fæces will turn yellow, and the Jaundice will be removed. In this Caſe it is eaſy to perceive, that from the Milk turning ſowre in the Stomach, a Coagulum is formed, which being propelled into the Duodenum, ſtuffs up that Inteſtine and obſtructs the Mouth of the common biliary Duct; ſo that the Bile is obliged to regurgitate into the Liver and Vena Cava, and mixing with the whole Maſs of Blood, it tinges the Skin of a yellow Colour; but after removing the obſtructing Coagulum which prevented the Bile from paſſing into the Inteſtine, all the Symptoms then diſappear. But the thing will appear ſtill more evident from the bilious Cholic of *Sydenham*, which that juſt Writer has very well deſcribed, but did not underſtand that the Seat of it was in the Liver. They who are taken with this Diſeaſe are oppreſſed with intolerable Anxieties in the Præcordia beyond Expreſſion, which are followed with Pains and Convulſions in the Abdomen, with ſo ſevere a Cholic, that the ſtouteſt Man who little fears any Diſorder is obliged to fill the whole Neighbourhood with his Cries from the ſevere Torture of the Diſeaſe. After the worſt Symptoms ſudden Reſt follows, and the Patient forgets all his Pains in Sleep; but after Sleep the Urine is voided of a Saffron Colour, and the whole Skin appears yellow, with a ſort of Weakneſs throughout the whole Body. This Colour of the Skin degenerates by degrees into a black, and after a few Weeks Time vaniſhes; ſo that the Patient ſeems to be well, but the Signs are unfaithful, for the Diſorder with which they were before tormented, returns and again goes off, and thus alternately; in which manner they are tormented at Intervals, 'till they are exhauſted and waſted away.

Upon opening the Bodies of theſe Patients after Death, the common Duct of the Bile is generally found obſtructed with ſmall Stones, the Duct itſelf appearing ſurprizingly dilated, inſomuch that it has ſometimes equalled the Vena Portæ. And this is the Hiſtory of the Diſeaſe and its Courſe, namely, an Obſtruction in the common biliary Duct, which prevents the Bile from being conveyed into the Inteſtines, whence it is by degrees accumulated, fills and diſtends the Gall-bladder and cyſtic Duct to ſuch a degree as that they are ready to burſt, and have been ſometimes ſeen capable of holding a Pint; from hence ariſe thoſe ſurprizing Anxieties of the Præcordia, which therefore by the Conſent of the adjacent Parts, brings on a Convulſion of the abdominal Muſcles and Diaphragm, which cauſes vomiting, *&c.* By the various Endeavours or Strainings to vomit, the Bile is at length drove back through the hepatic Ducts into the Liver and Vena Cava; in conſequence of which, the Blood and whole Skin are tinged with a yellow Colour, the biliary Ducts are then ſet at Liberty from their over Diſtention, and all the Torments are eaſed; but more Bile being by degrees ſeparated and accumulated as before, the biliary Ducts are again diſtended ſo as to cauſe a Return of the former Pains and Convulſions: after this a ſecond Criſis follows, and the Bile is repelled into the Vena Cava, ſo as to infect the whole Maſs of Blood. But the Reaſon why a Dropſy follow is, becauſe the Bile ſerves like a natural Soap to attenuate the Chyle and diſſolve its Viſcidities ſo as to appear uniform; therefore when this is mixed with the Blood, it diſſolves the ſame into a mere Water. But that the Bile does paſs into the Blood is demonſtrated even by the Eye with a Microſcope. I have often viewed the Eyes of People in a Jaundice with a Magnifier, and have perceived that the yellow Colour of the Adnata Tunica aroſe from the Bile which was not diſcharged into the Inteſtines, but returned into the Blood, whence the Skin appears yellow, and the Fæces were diſchaaged of a white or aſh Colour. The like Diſorder ſeems to ariſe from certain Poiſons, from whence Convulſions follow, by which the Orifice of the common Duct of the Bile being violently contracted, a Vomiting and Jaundice enſue, but ſuch as ſoon terminate in Death. Thus thoſe who have been bit by a Viper, ſuffer excruciating Pains with a convulſive Motion in the Hypochondria, and within two or three Minutes time the whole Skin turns yellow.

[9] All fat Aliments, ſuch as Butter, Lard, the Livers of Fiſh, *&c.* are very reliſhing and ſweet while recent ot freſh, and are ſo mild as not to offend even the naked Eye, or a Nerve which has been laid bare; but if thoſe Subſtances are taken in a larger Quantity than is capable of being digeſted by the vital Powers, they grow bitter, rank, yellow, riſe up into the Throat, and are ſpit out in the Form of Oil, which is inflammable. Thus it is evident, that the ſweeteſt Oils may be ſo altered by ſtagnating with the Heat of the Body, that they appear to be of a very oppoſite Nature. The ſame Alterations doubtleſs ariſe in the oily Bile of the Liver, after it has ſtagnated ſome time in the Gall-bladder. For I have experienced that the hepatic Bile is ſweet to the Taſte, and it is even ſweet when it comes to the Gall-bladder, provided there is no Mixture of the cyſtic Bile; for nothing is more agreeable than the Livers of Fiſh, which nevertheleſs have the Bile in the Gall-bladder extremely bitter.

[10] The Ear-wax is ſeparated from Cells or Follicles in the Skin of the Auditory Paſſage, being

at firſt thin and inſipid, ſerving to anoint the nervous Membrane which is ſo extremely ſenſible, and to defend it from the Injuries of the external Air; but the ſame Cerumen or Ear-wax, which was inſipid after the Parts had been well cleanſed of a mild and fluid Conſiſtence, does by ſtanding only inſpiſſate, turn yellow, and become extremely bitter. But there are the like cerumenous Follicles, ſo called by *Nucke* and *Ruyſch*, ſeated in the Membranes of the Gall-bladder; and by theſe Follicles the Bile is ſeparated from the arterial Blood more acrid, bitter, and truly ſaponaceous, which being diluted by the hepatic Bile, forms a Lixixium extremely well adapted to diſſolve Viſcidities, and reduce the groſs Parts of the Chyle to an uniform Fluid. Therefore there ſeems to be two Kinds of the cyſtic Bile; the one venal, brought from the Liver by the hepatic and cyſtic Duct, which by ſtanding becomes more bitter; the other arterial, being formed in the Follicles of the Gall-bladder itſelf, and ſo extremely bitter, that one Drop will tinge a thouſand of Water with a very remarkable Bitterneſs.

11 Theſe three Kinds of Bile tinge a large Part of the Duodenum and Colon, and being intimately mixed with the Chyle, occaſions the Fæces to be afterwards diſcharged of a yellow Colour. But yet the Bile does not always continue mixed with the Chyle, which is always found white and ſweet in the lacteal Veſſels: nor does it periſh with the Fæces, which have alſo no Bitterneſs; it therefore follows, that the principal and moſt lixivial Part of the Bile is abſorbed again by the meſenteric Veins, and returned to the Liver, to be there ſeparated again; from thence to be ſent to the Inteſtines, to be there again abſorbed, and thus to repeat its Courſe many times.

§. 349. All

§. 349. All that has been here advanced, is confirmed by the Diſcoveries of *Gliſſon*, *Verheyn*, and *Perault*, who have obſerved numerous *Ducts* [1] running from the Liver and porous Hepatics, to their Inſertion into the Gall-bladder, into which they continually diſcharge the Bile.

[1] Theſe are very well deſcribed in the uſeful Treatiſe of the celebrated *Perault*. The induſtrious *Du Verney* diſſected various Animals with great Artifice in Company with *Perault*, who delineated what *Du Verney* diſcovered, as being very ſkilful in the Art of delineating.

§. 350. From all which (§. 338 to 349.) the following Deductions appear to be true; 1. That the hepatic *Artery* [1], and its particular Diſtribution (§. 340.), is extremely ſerviceable towards Life, Nutrition, and Heat, contributing alſo to the *Propulſion* [2] of the hepatic Humours, as well as to their Secretion and Expulſion, for which Purpoſe it is wonderfully diſtributed through the very fine external Membranes of the Liver. 2. That from the Extremities of this Artery, there are great Numbers of Lymphatics, which are at firſt inviſible in the Liver; though from theſe are formed the viſible *Lymphatics* [3], which do not diſcharge themſelves into the Vena Portæ, but into the Receptacle of the Chyle at the Loins. 3. That there are *Veins* [4] which receive the ſuperfluous Blood from the hepatic Artery, after the Lymph has been thus ſeparated;

ted; which Veins convey the remaining Blood into that Part of the Vena Azygos, which is below the Diaphragm. 4. That all the Viſcera of the Abdomen, which are ſubſervient to Chylification, ſuch as the Spleen, Omentum, Stomach, Pancreas, Meſentery, Inteſtines, do all in ſome meaſure ſerve the *Liver* 5, by ſupplying it with their venal Blood after it has been wonderfully changed in each of thoſe Viſcera. 5. That Veins may be ſo altered, as nearly to *reſemble* 6 Arteries, as well in their Make and Strength, as Uſes. 6. That *Secretion* 7 may be made from the venal Blood. 7. That a Portion of the Blood propelled by the Heart, becomes *twice* 8 arterial and twice venal before it returns again to the Heart. 8. That the Courſe of the Humours in theſe intermediate Veſſels are extremely weak and *ſlow* 9. 9. And therefore it was neceſſary for the Liver to be ſeated near, and attached to the Diaphragm. 10. Whence it is eaſy for Stones, glutinous Concretions, Worms, Sordes, and the like, to be formed or generated about this Viſcus in thoſe who neglect the proper *Exerciſes* 10 of Body, from whence ariſe a large Train of Diſeaſes. 11. That the whole Office of the *Spleen* 11 is to be ſubſervient to the Liver in the Formation of the Bile. 12. And from thence ariſes the Affinity and *Dependance* 12 of the Diſorders, which follow in one Part from thoſe of the other; as alſo with reſpect to the healthy Condition of one depending on that of the other. 13. That the *Mat-*

ter [13] of the Bile has a different Origin from that of all the other Humours, as is evident from a chemical Analyſis. 14. That there is here a very particular Kind of the Blood's *Circulation* [14], the like of which has never yet been diſcovered in any other Part of the Body. 15. That there is a ſort of Similitude betwixt the Sinus of the Vena Portæ and the *Heart* [15] with reſpect to their Action; as alſo betwixt the five Branches of the ſame Sinus, and the Arteries which ariſe from the Ventricles of the Heart. 16. That the Cure of *topical* [16] Diſorders is in no Part more difficult to perform than here. 17. And yet that there are not ſo many Viſcera, Veſſels, Tumours, and Cauſes *employed* [17] towards the Formation of any one Juice beſides in any Part of the Body, as we here ſee concur for the Production of the Bile. 18. Which muſt therefore be one of the moſt uſeful, extenſive, and efficacious Means towards the Converſion of our foreign alimentary Juices into the Nature of nutritious *animal Fluids* [18]. 19. And that therefore the Bile is no *Excrement* [19]. 20. But that there are at leaſt two Kinds of it. 21. And finally, that the Liver operates more immediately for the Formation of the Chyle than of the Blood, and therefore may be *rather* [20] eſteemed one of the principal chylificative, rather than a *ſanguificative* [21] Organ.

[1] It by no means ſeems probable, that ſo ſmall an Artery ſhould carry ſo large a Quantity of Blood into the Liver, as is required for this Sepa-

ration of the Bile; and therefore the hepatic Artery ſeems to be given to the Liver, as the bronchial Artery to the Lungs, namely, to nouriſh the ſolid Fibres of the Liver; for which Purpoſe it was therefore neceſſary it ſhould be diſtributed throughout every Point of the Liver, ſince the venal Blood does not nouriſh: Hence it is that all Parts of the Body which receive and tranſmit the venal Blood, are not nouriſhed by that Blood, but by particular Arteries of their own, as in the Heart, Lungs, and Liver. Hence it is that a Liquor being injected by the hepatic Artery, neither returns by the Vena Cava, nor through the Pori Biliarii, being wholly ſpent in the ſolid Fibres of the Liver. But if the Vena Portæ be injected, the coloured Liquor ſoon flows into the Vena Cava, and into the Pori Biliarii.

2 The Blood of the Vena Portæ is the moſt remote from the Heart, and is therefore the coldeſt; nor is it capable of acquiring Heat, becauſe it is deſtitute of that Attrition and Friction of the Arteries, from whence only the Heat of the Blood ariſes. The hepatic Artery therefore in ſome meaſure warms the cooler Blood of the Vena Portæ. But as Veins are deſtitute of all Pulſation, therefore the Arteries are generally diſpoſed by the Sides of the Veins, that by their continual Pulſations the more ſluggiſh venal Blood might be drove forward: and this Action is ſo conſiderable in the hepatic Artery, that from thence the Ancients imagined that there was a Pulſation in the Vena Portæ itſelf. It is worth Obſervation, to ſee how exactly *Euſtachius* has figured the Arteries and Veins accompanying each other; which is no leſs true in the Liver, where every Branch of the Vena Portæ is followed by the hepatic Artery, in the ſame manner as the Emulgents and Branches of

the Cava, accompany each other very exactly. This Concourſe of the hepatic Artery and Vena Portæ throughout the Liver, was long ago obſerved by *Gliſſon*, who injected them with Ink; but they have been ſince more evidently demonſtrated by the more accurate Injections of *Ruyſch*. Theſe are therefore the Reaſons why the hepatic Artery does not extend itſelf beyond the Bounds of the Capſula Gliſſonii.

3 If a Ligature is made upon thoſe Veſſels by which the Liver communicates with the reſt of the Body in a living Dog, while yet breathing, namely, upon the meſenteric Vein, you will perceive the whole Surface of the Liver, with its ſuſpenſory Ligament and the adhering Omentum, ſpread on all Sides with lymphatic Veſſels; and upon removing the Ligature they all ſuddenly diſappear. *Bilſius* perceiving this, thence deduced an Hypotheſis, that the Lymph was prepared in the Liver, and from thence aroſe great Diſputes in *Germany*, *Denmark* and *Holland*. But there is no great Difficulty in reconciling thoſe Controverſies; for all the Veſſels of the human Body are not ſanguiferous, ſince there are an infinite Number of different Kinds, all whoſe Diameters are ſo ſmall as to exclude the red Parts of the Blood: it was therefore neceſſary for as many different Humours to be prepared, as there are Claſſes of Veſſels to be filled. Some of theſe more ſubtle Juices are ſpent in nouriſhing the Parts, while the reſt return to the Heart for the future Uſes of the Body, to which they are deſtined. There muſt therefore be as many Orders of Veins, as there are Series of Arteries. Now the ſuperfluous Parts of theſe more ſuble Humours which were brought for the Nutrition of the Liver by the hepatic Artery, divided into the ſmalleſt Branches, are returned by the lymphatic Veſſels

of the Liver, which diſcharge into the Receptacle of the Chyle whatever redundant Humours they abſorbed in the Liver; in the ſame manner as the more ſubtle Humours return from the Parts of the Thorax into the thoracic Duct, as alſo thoſe from the Head are diſcharged into the internal jugular Vein and its Sinus. There is therefore nothing peculiar to the lymphatic Veſſels of the Liver, more than what we obſerve in the other Viſcera. (See §. 345.)

[4] As the Liver is furniſhed with a peculiar Artery for its Nutrition, ſo it has alſo ſmall Veins correſponding to that Artery, which paſs from the external Surface of the Liver to the Vena Azygos, or elſe to the Vena Cava under the Diaphragm, which Veins we find deſcribed in *Bartholin.* I have myſelf obſerved Veins correſpending to the bronchial Artery, paſſing out of the Lungs in their back Part towards the Vertebræ, and terminating in the Vena Azygos in living Dogs. And that the ſame Mechaniſm obtains in the Liver we may readily believe; for the external Membrane of the Liver is a continuation of the Peritonæum, which involves the Inteſtines, Gall-bladder and Liver itſelf with the lower Surface of the Diaphragm, whence the abdominal Viſcera are not contained in the Peritonæum as in a Cavity or Bag, but as it were wrapped up in a Cloth, forming a diſtinct Bag for each Viſcus. By inflating under the external Membrane of the Liver, you may preſs the Inflatus ſo as to make it run over all the Surface of that Viſcus, and even round the Gall-bladder and Diaphragm itſelf. But the Vena Azygos is lodged under this ſame Production of the Peritonæum, in which the Viſcera are confined, and therefore the ſhorteſt way from the Surface of the Liver is for the Blood to paſs into that Vein. But no

Anatomiſt takes any notice of this Communication betwixt the Vena Azygos and the Liver, except *Sammichelli* in *Bartholin* as before mentioned. But the ſame Mechaniſm alſo takes place in the Inteſtines; for even in them the Blood which was brought for their Nutrition does not return through the Vena Portæ, but by Veins leading into the Cava, which are of a different Make, Diſpoſition and Termination, as *Ruyſch* acquained me in his private Letters, ſoon after he made the Diſcovery, and as he has ſince publickly deſcribed.

[5] For even the Liver, Gall-bladder and Pancreas are all ſubſervient to one Inteſtine the Duodenum, ſince the hepatic Bile, and the more bitter cyſtic Bile, together with the ſalival Juice of the Pancreas, are all poured into and mixed with the alimentary Maſs in that Inteſtine.

[6] The Branches of the Vena Portæ in the Liver are in effect real Arteries, they only want the Pulſation: nor am I poſitive whether or no the ſtrong muſcular Capſule of *Gliſſon* does not in ſome meaſure endow them with a vibratory Motion.

[7] This is the only Inſtance that we are acquainted with, of Secretion made from the venal Blood; though *Raw* alſo ſuſpected, that there was ſomething of the ſame manner of Secretion made in the Depoſition of the Medulla of the Bones.

[8] Namely, the Blood of the cœliac Artery, and the two Meſenterics, are diſcharged after the uſual manner into the correſponding Veins; that is, into the Branches of the Vena Portæ, in which the Blood does not paſs as uſual towards the Heart, but is conveyed by a particular Mechaniſm to the venous Sinus of the Porta, where it becomes arterial again a ſecond time, paſſing through the ſmalleſt converging veſſels of the Liver; after which it returns towards the Heart by Branches of the

Vena Cava, in which Courſe it becomes a ſecond time venal. Hence we may obſerve, that *Harvey* ought not to have abſolutely laid it down as an Axiom, that the Blood's Circulation is from the Heart through the Arteries into the Veins, and ſo to the Heart again; for this Canon or Rule does not hold univerſally true, unleſs we except this Mechaniſm in the chylificative Organs.

[9] The Fabric itſelf of theſe Veſſels demonſtrates the Slowneſs of the Blood's Motion. For the Blood of the Vena Portæ loſes almoſt all the Force which it received from the Heart, in its Paſſage from thence through the Extremities of the Arteries opening into this Vein; in the ſame manner as the venal Blood throughout the whole Body is ſent back to the Heart almoſt entirely by the Motion of the Muſcles. But there is not an eaſy Paſſage towards the Heart allowed to this Blood, ſince it is to overcome a ſecond Reſiſtance, namely, the converging or arterial Extremities of the Porta in the Liver, which it would never be able to overcome, if it was not to be forwarded by the ſtrong Action of the Diaphragm and abdominal Muſcles in Reſpiration by which the Compages of the Liver are compreſſed and agitated. I formerly (*Anno* 1696) ſpent ſome time with my Friends in diſſecting living Dogs, in which upon opening by an inſtantaneous Inciſion, I found the meſenteric Veins extremely ſmall, but they ſeemed by degrees to enlarge, and at length they became quite varicoſe and extremely turgid. This Appearance may be eaſily explained, inaſmuch as the Blood of the Vena Portæ is not drove forward in its Veſſels without the Aſſiſtance of a Compreſſure from the Muſcles of Reſpiration; and therefore this Preſſure being removed by opening the Abdomen, the Blood will not paſs ſo freely through the

Liver as before, but will be gradually accumulated, ſo as to diſtend the Veins which are uſed to diſcharge themſelves into the Sinus of the Portæ; for I look upon the Preſſure which is returned by the Peritonæum upon the Veins of the abdominal Viſcera, by the alternate Contraction of the Muſcles, to be as a kind of ſecondary Heart, to urge forward the Blood of the abdominal Viſcera.

[10] The learned Part of the World daily experience this Truth to their great Mortification; for many of them eat as much as a Ploughman, but do not digeſt it with the ſame Powers: for while the Ruſtic is employed upon his laborious Exerciſes, the ſtudious Perſon ſits down to his beloved Study without the leaſt Motion of Body, while his Reſpiration is extremely ſlow, or ſcarce perceptible, and his Body inflected towards the Books: Thus by degrees ſooner or later the Studious become hypochondriacal, unleſs they ſet apart a few Hours for walking and Exerciſe before Dinner upon an empty Stomach, or elſe addict themſelves to ſome innocent Labour. The ſame is alſo true with reſpect to thoſe who have the Adminiſtration of public Affairs, who live richly and plentifully, but are long confined to their Chambers, meditating with the ſtricteſt Attention of Mind upon the Affairs of others, which are made their own Concern. But Reſt is equally deſtructive to Brutes, as well as the human Species: and it is no uncommon thing to find the Livers of Sheep ſo far eat up by a ſwarm of little Fiſh called Flukes, that there is nothing left but its external Membrane like an empty Bag. And this more eſpecially happens to thoſe tender fibred Animals after the autumnal Rains. Now in theſe Animals the Mouths of the lacteal Veſſels ſeem to be ſo far relaxed, as to admit the Ova of theſe Inſects; at

which we need not wonder, if we conſider that it appears from the Obſervations of *Lewenhoec*, that an Inſect equal to the hundredth Part of a Grain of Sand, lays three thouſand Eggs within the ſhort Time that it remains under the Inſpection of the Eye by the Microſcope. Even the Liver has been obſerved to be thus eat up by Inſects in the moſt voracious of Animals the Lion. But in the Oxen-kind, after reſting the whole Winter, all the biliary Paſſages are lined with a ſtoney Cruſt: for the Bile being one of the moſt viſcid of the animal Juices, is ſcarcely moved of itſelf, unleſs urged forward by the Efficacy of Reſpiration; and therefore by the Winter's Reſt, it concretes or condenſes into a ſolid friable Maſs. There are in ſhort two Viſcera, on which almoſt all chronical Diſeaſes depend, namely, the Lungs, from whence a Tabes and its various Conſequences; and the Liver, from whence the innumerable Train of ſlow or chronic Diſorders.

[11] The Spleen, as we obſerved before, is to prepare the Blood ſo as to be very dilute and fluid, in ſome meaſure to correct the ſlow Motion of it through the Vena Portæ in the Liver.

[12] Thus any one of theſe Viſcera being obſtructed, the reſt partake of the Diſorder: from whence it is that a Diſorder in theſe Parts has by the Ancients been called of the hypocondria, or hypochondrical, in relation to all the Parts ſeated immediately below the falſe Ribs, without any Diſtinction of the Liver, Spleen, *&c.*

[13] The Matter of the Bile is neither an alcaline fixed or volatile Salt, but an Oil attenuated with a ſmall Quantity of Salt, ſo as to reſemble a kind of Soap; which is extremely bitter in the Gall-bladder, but very thin and not bitter in the Liver; ſo that from a Conjunction of the cyſtic and he-

patic Bile a very powerful animal Soap is formed (§. 98, and 99.)

[14] This Peculiarity of the Circulation ſeems not to have been ſufficiently conſidered by any one. A Circumſtance which put me upon framing a new Hypotheſis, was the Inſpection of the Body of an Officer in the Army, who had gone through all the Degrees of the yellow, green, and black Jauudice, accompanied alſo with a bilious Cachexy, and at length a Dropſy of the Abdomen and lower Extremities. Leave was with ſome Difficulty obtained by the Phyſician, who had diligently attended the Diſeaſe, to examine into the State of the deceaſed Body. Upon opening the Abdomen, the Liver appeared ſcarce equal to a Hand's Breadth, and about the ſame Thickneſs, but as tough as Leather itſelf, while the Spleen was twelve times as large as is uſual in a healthy Body. I uſed my utmoſt Attention to enquire into the bottom of this Matter, and at laſt perceived that the Liver being obſtructed, the Blood therefore ſtagnated, and was collected in the Veins which lead to the Sinus of the Porta, until at length vomiting and convulſive Motions occaſioned the Blood to alter its Courſe, and to paſs in a contrary Direction through the correſponding Arteries into the Aorta itſelf. Nor does this retrograde Courſe of the Blood ſeem improbable, if we conſider that there are no Valves to reſiſt its Return, except in the Vaſa brevia: but in the mean time it is evident from Hydraulics, tha if a greater Preſſure or Reſiſtance be made upon the Liver than at the Extremities of the Arteries, the Blood will then return into the Arteries, inſtead of flowing towards the Liver. Upon deſiring my Friend *Ruyſch* to make the Experiment, he anſwered, that his Injection returned from the meſenteric Veins into

to the Arteries; but that upon tying the meſenteric Veins at the Liver, Wind being inflated found a Paſſage through the Arteries into the Cava. One may eaſily conceive what miſerable Diſorders muſt ariſe from ſuch a Perverſion of the Blood's Courſe.

[15] This Sinus has ſtill a greater Reſemblance to the Heart in a Fœtus, who whilſt living in the Mothers Womb, receives all the Blood which is brought by the umbilical Veins into the Sinus of the Vena Portæ, from whence it paſſes by a ſhort Courſe into the Cava and Heart. But in Adults all the Blood is not indeed derived into the Porta, but only that Part of it which has been ſent through the Viſcera of the Abdomen. In fact the Structure of the Sinus of the Vena Portæ is like that of the Heart: for it appears from the Obſervations of *Malpighi*, that the Heart which firſt appears in the Chick, is no more at the Beginning than a Vein variouſly inflected, round which a Muſcle afterwards grows; but what elſe is the Sinus of the Vena Portæ than a Vein encompaſſed with a Muſcle? The true Uſe of the Heart is to receive all the Blood from the Veins and propel it into the Arteries, that the ſeveral Secretions may be duly made from it in the ſeveral Parts where thoſe Arteries terminate. But the ſame is the Action of the Sinus of the Vena Portæ in Adults, with reſpect to the chylificative Organs. For to the Liver comes all the Blood of the Stomach, Inteſtines, Omentum and Spleen; and the ſame Blood is propelled from the Sinus of the Vena Portæ into its arterial or converging Branches, diſtributed through the Liver, where the Bile is ſeparated from this Blood. But the Parallel runs even further, for as the Heart has a ſubſidiary Organ of its own, to attenuate the Blood, namely, the Lungs; ſo the Liver is provided with a Viſcus deſtined to the ſame

Office, namely, the Spleen. No Objection can be therefore made to our calling the Sinus of the Vena Portæ a kind of Heart in the Abdomen for the Preparation of the Chyle.

[16] Among a thouſand Cures of acute Diſeaſes, there is hardly one perfect Cure to be alledged, either of a Dropſy, Jaundice or ſplenetic Diſorder; and even among a hundred chronical Diſeaſes, there is hardly one whoſe principal Seat or Cauſe is not in the Liver. For the Medicines which are deſtined to open Obſtructions of the Liver, are obliged to take a very long and round-about Courſe through the lacteal Veſſels to the Heart, from thence through the ſmall Arteries of the Inteſtines and other Viſcera; and from theſe Arteries again into the meſenteric and other Veins leading to the Sinus of the Porta in the Liver: and therefore we cannot wonder that there are ſo few Medicines as yet found capable of retaining their Nature and Action through ſo long and winding a Paſſage. Beſides this we may add that the Powers of Nature, which form Criſes in other Parts of the Body, do not in this Part afford any Aſſiſtance to the Phyſician; for the Force of the Heart is no where more weak and diſtant, and the Blood has not here that Action of the Arteries by which its impervious Matter may be ſo attenuated as to paſs off in a critical Diſcharge, as it ſometimes does, for inſtance, by ſpitting in a Pleuriſy; but the Humours being here thick or viſcid and carried with a very ſlow Motion, are notwithſtanding all Nature's Precautions to the contrary, much inclined to form incorrigible Obſtructions. The only Relief that can be expected in theſe Caſes muſt reſult from the exciting of a ſlight Fever, at the ſame time uſing diluent and attenuating Medicines, which being partly abſorbed by the meſenteric Veins, a ſmall Portion of them

may paſs immediately to the Liver, without firſt pervading the Heart. Of this Nature are the Whey of Milk, Decoctions of Graſs-roots, purging Waters drank plentifully, *&c.* which if accompanied with riding in a Chair, are almoſt a ſpecific Cure for Obſtructions of the Liver. *Hippocrates* cured his hypochondriacal Patients only with Mead. Hence the Method of treating hypochondriacal Diſorders with the Bark, is not ſo agreeable to Nature, inaſmuch as it is an Aſtringent, and ſuppreſſes the ſlight Fever, by which only we can hope for a Reſolution of the obſtructing Matter in the Veſſels of the Liver.

[17] The Ancients being ignorant of the lacteal Veſſels, therefore ſuppoſed that the Chyle was drank up in the Inteſtines by the meſenteric Veins, and by them conveyed to the Liver; which Viſcus appearing above all others like Blood, changed the Chyle into that Humour, ſince they could find none of the Chyle in the Vena Cava; therefore that the Chyle being converted into Blood in the Liver, was carried from thence by the Vena Cava to be diſtributed throughout the whole Body, the Liver being the common Origin of all the Veins. But, 1. The meſenteric Veins do not abſorb the white and nutritious Part of the Chyle, ſince that milky Juice is conveyed by the Lacteals to a Part very diſtant from the Liver. And, 2. There is no Power in the Liver by which it can immediately convert the Chyle into Blood; inſomuch that if Sanguification itſelf is deſtroyed, the Liver will be alſo ſpoiled, or at leaſt afflicted a long time with chronical Diſorders: whence it follows that the Liver is only a chylificative Organ, and that its Office is to prepare the Bile.

[18] The Spleen, Omentum, Meſentery, twofold arterial Action, and twofold venal Mixture, all

concur to prepare this one Liquor. The Semen has alſo a long Courſe for its Preparation, and paſſes through other ſmaller Arteries, where the ſeminal Arteries change into the Beginning of the ſpermatic Ducts; while other Veſſels, like Arteries, form the convoluted Veſſels of the Epididymis terminating in the Ductus Higmori. But this Analogy is ſomething more remote from the Arteries.

[19] The Chyle, as yet a foreign Juice, is ſo viſcid when it firſt approaches the Mouths of the lacteal Veins, that it would not be capable of being abſorbed, unleſs the Bile which there mixes with it, render'd it more fluid, dilute, and more nearly approaching the Nature of animal Juices. But this Action of the Bile muſt be very conſiderable, to produce ſuch Effects after it has been ſo much diluted and diſcharged from its proper Receptacle. But that the Bile is the moſt exalted in Nature among the animal Juices, is demonſtrated from its Cauſes, ſince it ſuffers more from the Action of the vital Powers, than any other Humour in the whole Body: for the Elaboration of all the Humours is reducible to the Action or contracting Force of the Solids, and the Mixture or Addition of other Juices, which are already of our own Nature. The firſt of theſe Actions is communicated to the Humours in the Arteries, and the latter in the Veins: but the Bile has been twice arterial and twice venal, as we before demonſtrated.

[20] An Excrement is ſomething caſt out of the healthy Body by the vital Powers, ſo that it never afterwards mixes again with the circulating Humours: but the Bile is not diſcharged out of the Body, ſince it mixes with one of the moſt uſeful Juices the Chyle, in the Formation of which it has ſo great an Efficacy, that the whole Buſineſs of

Chylification ceaſes immediately, if the Bile is not mixed as uſual. This was firſt demonſtrated by *Helmont*, (as we obſerved in §. 102.) In the moſt voracious Animals and gluttonous Men, (ſuch as was the Waterman or Gally-rower of *Veſalius*,) (1.) the Bile pours itſelf either into the Pylorus, or into the Stomach itſelf. The Ancients had ſome Notion of this thing, ſince they tell us that thoſe who have a riſing of bitter Bile in their Throat are extremely hungry. (2.) But in moſt People, and in brute Animals, the Bile diſcharges itſelf into that Part of the Inteſtines, where the lacteal Veſſels begin to ariſe. (3.) In the moſt voracious Fiſh, who digeſt their Food without Heat or Maſtication, the Liver extends itſelf for a long way, together with the inteſtinal Tube, and the Bile is diſcharged in theſe Animals into the Inteſtines at a conſiderable Diſtance from the Stomach. But in no Animal is the Bile diſcharged into the Rectum, which yet would have been the moſt proper Receptacle, if the Bile was an Excrement.

[21] Not that the Chyle itſelf is perfected by this Humour, but that the Liver prepares the ſame Humour for giving the Chyle ſuch a Diſpoſition, as may enable it to paſs through all the ſmall Veſſels, and through the narrow Extremities of the pulmonary and other Arteries, without injuring the Health of the Animal. Milk and Chyle very eaſily turn to Curds and Whey; to prevent which, the Country People know how, namely, by adding of Sugar, Soap, Bile, *&c.* For when theſe are mixed, no Cheeſe can be made from the Milk. This then is the Uſe of the Bile with reſpect to the Chyle, namely, to render it a ſmooth, uniform Juice, and prevent its Parts from ſeparating or curdling, ſo as to be afterwards impervious in the Veſſels.

Of the Action of the KIDNEYS.

§. 351. HAVING already treated ſufficiently concerning the Pancreas, Meſentery, Stomach, Inteſtines, *&c.* ſubſervient to Chylification, the Order of the Parts requires of us next to explain the Action of the Kidneys.

§. 352. The *Kidneys* [1] are ſo ſituated and connected, that the *Motions* [2] of the adjacent Parts promote the Secretion and Excretion of the Urine, and this more eſpecially in the right Kidney; but both of them are defended *under* [3] the Membrane of the Peritonæum, and by the hard *Fat* [4] with which they are inveſted. They receive Glands faſten'd at their top, inclined a little towards their Excavation, which is almoſt *conſtantly* [5] the Situation of theſe Glands; though ſometimes being removed from the Surface of the Kidneys, they adhere firmly to the Diaphragm, being hardly ever of the ſame Form in two different People, nor of the ſame Magnitude; but they are depreſſed, or of a flat Figure like a little Placenta, and furniſhed with Arteries and Veins, varying in their Origin and Diſtribution. The Kidneys are next furniſhed from the deſcending Aorta, each with a *conſiderable* [6] Branch, or ſometimes with more Branches than one; from which Arteries the Kidneys again receive another Tunic, and dividing themſelves into four, five, or more Branches, and theſe again into much ſmaller Arteries, they at laſt diſappear in very thin Circles or Arches diſtributed throughout the whole Subſtance of the Kidneys. Theſe laſt Branches of the Arteries running in a vermicular Courſe, mutually uniting with each other, and ſeparating again, ſeem to conſtitute, as it were, *Heaps* 7 or Glands, But from the Extremities of theſe Arteries the reductory ſmall Veins ſeem to ariſe, which gradually *unite* [8] into larger, terminating at length in four or five conſiderable Branches, which end in one or more Veins called the Emulgents; and at the ſame time lateral Ducts alſo ariſe from thoſe Extremities of the Arteries, which being almoſt pellucid, receive and convey the Urine ſeparated from the ſmall Arteriolæ; and uniting together, they form many pyramidal Bodies, having ſeveral Angles, which at length terminate uſually in twelve membranous Bodies called *Papillæ* 9, into which many of the renal Tubes collected together open obliquely on all Sides, as well from within as without.

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[1] All ſanguineous Animals are found to be furniſhed with Kidneys. And although there are ſome who imagine that Birds are deſtitute of Kidneys, becauſe they have no Urethra; yet it is certain that all feathered Animals have Kidneys, and ſeparate as well as diſcharge Urine: But then in

Fowls there is no particular Paſſage for the Diſcharge of the Urine; but the Ureters are inſerted into the Anus, which the Ancients properly enough denominated *Uropygium (ex urina & natibus)*; ſo that the Urine is evacuated in feathered Animals together with the inteſtinal Fæces. Hence it is that many Animals of the Bird-kind diſcharge their Fæces in a fluid Form, as we frequently ſee in Hens; but when they ſit upon their Eggs, they do not diſcharge the drier Fæces for a conſiderable time, untill they have been firſt ſoftened by the affluent Urine. The Dung of Storks is white and fluid.

[2] I have frequently obſerved in opening living Dogs, that the Kidneys deſcend at the time of Inſpiration, and riſe up again at the time of Expiration. And in living Animals who are not opened, they readily receive a Preſſure from the circumjacent Parts, though not ſo conſiderable as the Spleen. Beſides this, they alſo receive a conſiderable Motion from the Muſcles of the Loins upon which they are incumbent, inſomuch that Stones are ſeldom formed in the Kidneys, except in thoſe who have a long time neglected the proper Exerciſes of Body. All the Cauſes which we have before enumerated, were neceſſary to move the Kidneys to forward the Urine from the Pelvis into the Ureter, that is, from a larger to a ſmaller Canal; and therefore when theſe Motions are not communicated for want of the Exerciſe of Body, the Urine ſtagnates and forms Calculi. It is alſo remarkable, that Brutes do not make Water freely after the Abdomen has been opened. But the right Kidney is moved more than the left, which is generally a little higher than the right; and therefore Calculi are more ſeldom found in the right than in the left Kidney. Add to this, that the Stomach being diſtended,

ed, may alſo compreſs the left Kidney, ſo that it cannot be moved to evacuate its Contents, which in this Viſcus is not promoted by any muſcular Force of their own.

[3] The Kidneys are not truly contained in the Cavity of the Abdomen, nor are the emulgent Arteries or Veins together with the Aorta and Vena Cava; for all theſe are only covered before by the Peritonæum, as they are incumbent on the Loins. So that the Blood which is at any time extravaſated from the Kidneys, does not flow into the Cavity of the Abdomen, as ſome have imagined, but betwixt the Loins and the Peritonæum into the cellular membrane. Even if the Kidneys are ſuppurated, an Empyema of the Abdomen does not thence follow, but the Loins only ſuffer; inſomuch that ſometimes a very large Abſceſs ſhews itſelf in the Back, which ſometime breaking either ſpontaneouſly, or by the Aſſiſtance of a Surgeon, there is a ready Paſſage for a Catheter to paſs into the Pelvis of the Kidney itſelf, in ſuch a manner, that the Urine has been ſometimes diſcharged through the Back by a grooved Probe or Director. Nephrotomy, or an Inciſion has been made upon the Kidney through the Back in ſome Caſes; and this bold Operation was performed by *Marchetti* upon the *Engliſh* Ambaſſador.

[4] The Kidneys are lined with Fat only on their external Surface, but have not the leaſt Fat on the Inſide; from whence we have a Saying, that the Kidneys, like covetous Men, are lean in the midſt of Fatneſs. The Kidney ſeems to be thus inveſted with Fat, to qualify the Acrimony and putrid Quality of the Urine, as well as to obtund the alcaline Salts, that they might not prey upon the Fabrick of the Gland itſelf, as *Malpighi* well obſerves. But this ſoft Fat gives way to the Kidney,

whenever it is diſtended by too violent Motion of the Blood. But this Fat is naturally of a drier and harder Conſiſtence than that in other Parts of the Body; and therefore when it abounds in too great a Quantity, it may ſo compreſs the Kidney, as to retain the groſs Parts of the Urine, while the more fluid are diſcharged, whence a Calculus may follow. And if in opening a dead Body there appears much Fat upon the Kidneys, one may be aſſured that the Perſon was inclined to the Gravel.

[5] *Euſtachius* was the Diſcoverer of theſe Glands, the various Conditions of which he has well expreſſed in his Tables, in the manner as they moſt frequently appear upon the Kidneys, inſomuch that they are ſcarce alike in the Kidneys of two different People; but yet he has never omitted theſe Glands, only placed them ſometimes nearer, and ſometimes at a greater Diſtance from the Kidneys, varying both their Figure and Situation. The Conſtancy of Nature in ſupplying the Kidneys always with theſe Glands, ſeems to argue that they have ſome Uſe towards the regular Secretion of the Urine; and perhaps they may be to ſeparate a kind of Liquor, or prepare the Blood, as in the Spleen, which by mixing with the venal Blood of the Emulgents, may ſupply that Defect of Fluidity, which ariſes in it from the Separation of its watry Parts. They very ſtrictly cohere with the Diaphragm, in ſuch a manner that they can hardly ever be at reſt; and therefore we never find any ſtony Concretions in theſe Glands. They have Arteries and Veins peculiar to themſelves.

[6] Large enough to receive one's Finger; inſomuch that hardly any other Viſcus has Arteries ſo large. And from this Largeneſs of the renal Arteries we may judge of the vaſt Quantity of Humours,

mours, which perpetually circulate in a given time through this no ſuch very large Viſcus. Theſe Arteries immediately depoſit their external Tunic, as in the Brain, as ſoon as they enter the Kidney, which ſerves to compoſe the external Tunic of the Viſcus.

[7] The Artery which goes to the Kidney, immediately divides itſelf into many Branches, which have a different Appearance in their Diſpoſition from thoſe in any other Part of the Body. For all the Arteries are extended to the convex Surface of the Kidney, where their ſmall Extremities are inflected in and out in a ſerpentine Courſe. Through theſe ſerpentine Branches neither Lymph, Milk, nor Chyle are ſuffer'd to paſs into the uriniferous Ducts, at leaſt in a healthy State, nor is there any Part of the Body in which ſo large Arteries ſo ſuddenly diminiſh into the ſmalleſt Branches; for the Arteriolæ, which ariſe from the larger Circles or Arches, are not at all thicker than a Hair of one's Head.

[8] For many Ducts, perhaps a thouſand, lie cloſe to each other and open their Extremities through the whole Surface of each Papilla, which diſcharge the Urine through open Pores into the Pelvis. But that the Urine might not return out of the Pelvis into the Papillæ, they are each of them armed with a kind of Membrane or Valve, which ſecludes the Mouths of the Ducts ſo as to permit the Urine to flow into the Pelvis, but prevent its Return. Through theſe Orifices the ceraceous Injection of *Ruyſch* being artfully impelled, makes its way even into the Pelvis of the Kidney from the Arteries. Theſe Tubuli or Ducts, which bear the Name *Bellini*, were ſo called from his diſcovering them before the Tables of *Euſtachius* were

found, in which they had been repreſented above one hundred and thirty Years before.

[9] Namely, every particular Branch goes to a particular Part of each Kidney, almoſt in the manner of a diſtinct Gland, as well in the human Body as in other brute Animals, though it is uſually repreſented otherwiſe. *Euſtachius* has demonſtrated this conglomerate Structure of the Kidneys in the Bear and Tortoiſe; for in theſe Animals the Kidneys appear compoſed of an Aſſemblage of many angled Glands, ſeparated from each other; each of which have an Artery and Vein, with a diſtinct Pelvis: all which Pelves meet together in one. In the Hedgehog the Kidney is compoſed, as it were, of a Heap of Glands like a Bunch of Grapes; and in the human Fœtus the Kidneys are divided into diſtinct Portions by the Fat; but afterwards theſe Portions unite into one larger Kidney, as hath been demonſtrated by *Euſtachius*, and ſince confirmed by *Ruyſch*; ſo that in adult People the Portions, which were before diſtinct, unite into one uniform Body, whereas in Oxen they remain diſtinct as long as the Animal lives. But though the diſtinct Portions thus unite into one uniform Body, yet there remains ſome of the Footſteps of their Diviſions; and there are as many diſtinct Papillæ, or pyramidal Bodies, as the Kidney was before divided into diſtinct Portions, uſually about twelve. But the Cauſe of this Alteration ſeems to be the Preſſure of the Arteries, compacting the dividing Portions together. Suppoſe twelve hollow Balls of Wax were to be aſſembled together, with each a diſtinct Tube or Stalk, they might by any external Force be urged together into one continued Maſs; but then the Bodies which were before globular will become hexagonal, and touch each other in plain Surfaces; but internally their Ducts will terminate

in a Point, ſo as to form a pyramidal Body, like unto thoſe which are called the *Corpora Pyramidalia* by *Malpighi* and *Bellini*; and thus the ſeveral Portions will be combined into one Kidney, tho' each of them remain capable of performing their diſtinct Office. But the Figure of theſe pyramidal Bodies reſults from a Combination of the Artery, Vein and Duct in the broader Baſis, at length terminating only in a ſingle Point, or a ſolitary uriniferous Duct, forming the ſmaller Part of the Pyramid.

§. 353. In the Subſtance of the Kidneys there are alſo found ſmall, round, hollow *Bodies* [1], inveſted on all Sides with the *ſmalleſt Veſſels* [2], furniſhed with ſmall Veins and Nerves, as well as with the ſmalleſt Arteries, and are continued even to the uriniferous Tubes: all which is confirmed by ſtony Concretions and other *Diſorders* [3] of the Kidneys, as alſo the Appearance of them in Hedgehogs, Tortoiſes, and in the human Fœtus. Hence therefore the Urine ſeems to be ſeparated two ways in the Kidney, namely, by a *glandular Apparatus* [4], and by the more ſimple vaſcular Apparatus of *Ruyſch* [5]; and this is alſo conformable to the Courſe of Nature in other Parts, as, for Inſtance, in the Liver: But this laſt Apparatus *Ruyſch* imagines, upon the ſtricteſt Enquiry, not to be Glands, but only Contortions, or Twirles of the ſmalleſt Arteries.

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[1] *Ruyſch* allows that there are certain Bodies which have the Appearance of Glands, concerning

ing which he has often changed his Opinion about them; but at length he determined, from the gigantic or tall Woman whom he diſſected, that they were reſolvable into real and continuous ſmall Veſſels, being nothing more than the Extremities of the Arteries. And to prove this, he urges a very cogent Argument, namely, that Liquors paſs directly from the Arteries into the urinary Pelvis, without forming any Knots or Diſtentions, which would certainly appear, if there was any intermediate Receptacle betwixt the Extremity of the Artery, and the Beginning of the uriniferous Duct. But this Experiment does not prove that there are no Glands: for the larger Veſſels might ſo conceal by their Diſtention the intermediate Follicles, as totally to obſcure them in his Preparations.

[2] *Malpighi* injected Urine mixed with Ink into the renal Arteries, which filled the ſmalleſt Arteries diſperſed in this glandular Apparatus, and all their Follicles were likewiſe diſtended with the ſame Liquor.

[3] In the Body of a Woman diſſected by *Malpighi*, the Kidney was found full of ſpherical ſtony Corpuſcles, which diſcharged ſtony Threads into the Pelvis, which was alſo full of Calculi.

[4] By which glandular Fabric, a ſmall Quantity of Urine ſeems to be ſeparated of a more acrid and groſs Nature than that diſtilled from the Veſſels, which is more watery and tinged or coloured by the other: And that Nature ſometimes uſes a twofold Apparatus for the Separation of a Humour, is evident, for Inſtance, in the Teſticle.

[5] By this ſimple or direct Courſe the Urine is immediately and continually diſtilled, at leaſt a greater Part of it, which appears thin, watery, and colourleſs: nor is there any other Way by which ſuch large Quantities of Urine are ſo ſpeedily evacuated after much drinking.

§. 354. But there is ſtill another Part of the renal Artery, whoſe Office is to ſupport the Warmth, and adminiſter the nutritious Matter neceſſary for continuing the Life of the Subſtance of the Kidney itſelf, and it is from the Blood of this Artery, that the Lymph ſeems to be ſeparated, which is ſo plentifully returned from the Kindney to the Receptacle of the Chyle, to be returned into the common Circulation; which Lymph is *healthy* or *ſound* [1], and not excrementitious, nor has it any Taſte of the Urine. From theſe Arteries alſo there are doubtleſs peculiar Veins, which ariſe correſponding to them, to return the ſuperfluous Blood.

[1] Namely, the Lymph which is redundant over and above what was conveyed by the lymphatic Arteries for the Nutrition of the Parts; which entring pellucid Veins, paſſes towards the Heart, without having any Communication with the watery Parts of the Urine. It is indeed commonly ſuppoſed that the Kidneys purge the Lymph; but the watery Part of the Urine is very different from the ſerous or lymphatic Part of the Blood, which are of a ſweet and gelatinous Nature, concreting with the Heat of boiling Water like unto the White of an Egg (§. 123.); whereas the Urine is a Lixivium, volatile, and very acrid (§. 380.)

§. 355. For the ſmalleſt Veins ariſing from the ultimate Extremities of the renal Arteries, (§. 452.) meeting together form larger Veins, whoſe Branches divide and meet in the ſame manner with the Arteries; and at length terminating in an uncertain Number of Trunks, they diſcharge the Blood remaining after the Secretion into ſome Part of the Vena Cava.

As for the Blood which returns from the renal Glands, that is diſcharged into the emulgent Veins and Cava; which was neceſſary, as the Blood of the Kidney has been in a great meaſure deprived of its diluting watery Parts; for of eight Pounds of Aliment, near two are diſcharged by Urine: and therefore the Blood of the emulgent Veins muſt be very thick, and ſtand in need of ſome Means for its Dilution.

§. 356. Now the renal Papillæ (§. 352.) diſtil the *Urine* [1] brought by the uriniferous Ducts into a large membranous Cavity called the Pelvis, furniſhed with a ſoft Fat of its own; in which Cavity being collected, *retarded* [2], and mixed, it is drove from the Pelvis into a narrower Duct called the Ureter, by which the Urine is at length conveyed into the Bladder.

[1] If warm Water be injected into the emulgent Artery, Part of that Water will enter into the Veins, and return to the Cava; and another Part of the ſame Water will diſtil through the uriniferous Ducts and Papillæ into the Pelvis and Ureter. But if the Kidney be firſt well waſhed clean by injecting Water, and after filling the Arteries with a fluid ceraceous Injection, you then expoſe the whole Kidney to macerate or putrify, the Tubuli Belliniani will then be found turgid with the Injection, and you will have an Opportunity of ſeeing

ing that every Point of the Papillæ detaches a little Cylinder of Wax into the Pelvis, in the ſame manner as the Urine was conveyed before. Theſe Tubuli therefore ariſe from the lateral Extremities of the ſmalleſt Arteries, and diſtil the Urine which they receive into the common Receptacle.

[2] This Slowneſs of the Paſſage of the Urine occaſions the frequent Formation of Calculi in the Ureter; nor could this Inconvenience be avoided, ſince ſuch a Receptacle was neceſſary to be made, as might forward the Motion of the Urine through the Ureters, and in a manner relax the Papillæ like a continual Bath, leſt if they ſhould be dried up, they might become impervious.

§. 357. Now there are *eleven* [1] or twelve membranous Canals, which ariſe from the Circumference of the Papillæ (§.356.) which they embrace, and receive the Urine which diſtils from them; and at length paſſing into three large Branches, they unite and form one large Pelvis; which *Pelvis* [2] terminates in a ſingle, thick and ſtrong membranous Canal, repleniſhed with *Arteries* [3], Veins, Nerves, and lymphatic Veſſels; alſo furniſhed with muſcular Fibres and *mucous Ducts* [4] for lubricating the Sides. This Duct, which is called the Ureter, deſcends firſt directly downward, but is ſoon after *inflected* [5] a little in its Courſe, which is always *under* [6] the Lamella of the Peritonæum, being of an *unequal* [7] Diameter in different Parts, till at length it is inſerted towards the Back and lower Part of the Bladder, at about the Diſtance of two Fingers

Breadth from its Neck, and as far from each other: but they here enter the Bladder by paſſing firſt through its external Coat, and running for about the Length of a ſmall Finger's Breadth obliquely betwixt that and the interior Coat; it then enters the Cavity of the Bladder by thruſting out its *round*[8] protuberant Fibres, which being continued downward, form a cylindrical or round Body of ſome Length, by which the Urine is prevented from flowing back into the Ureter when the Bladder is full; at which time its Coats being expanded, the opening is cloſed, and a free Paſſage allowed to the Urine to enter into the *Bladder*[9], while the cylindrical Body and oblique Inſertion of the Ureter prevent any thing from returning out of the Bladder, even though it be attempted by a conſiderable Preſſure.

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[1] The common Number is twelve, though there are ſometimes only ſix or eight, as *Euſtachius* repreſents in ſome of the Figures of his Tables; but this is ſeldom obſerved. The ſame Anatomiſt has given an excellent Figure, where, contrary to the common Courſe of Nature, there are twelve diſtinct Branches: for the Pelvis uſually divides itſelf either into two or three Trunks; if three, each Trunk correſponds to four Papillæ; but if there are four Branches, then each Branch terminates in three Papillæ.

[2] There are diſtinct Membranes which embrace each of the Papillæ, which Membranes being collected into one large Sinus form the Pelvis. About the Pelvis there is diſpoſed a large Quantity of Fat to facilitate the Motion of its Contents; for

when that Fat is conſumed, which naturally is abſorbed and conveyed into the Cavities of the Kidney, it occaſions ſevere Pains and other Diſorders.

[3] Hence therefore the Ureter may ſuffer all thoſe Diſorders, which are capable of invading any other vaſcular or membranous Part of the Body; namely, Inflammations, Suppurations, Scirrhoſities, *&c.* A Knowledge of which is neceſſary, in order for us to diſcover the Cauſes of Diſeaſes in theſe Parts. From Inflammation follows a Stricture of the Ureter, which cauſes an Iſchuria or Suppreſſion of Urine without any Fault in the Bladder. There was an *Engliſh* Miniſter at *Amſterdam*, who every Month was afflicted with this Diſorder, which gave way to the ſame Treatment which is neceſſary for all other Inflammations of the Body, namely, Phlebotomy.

[4] Theſe mucous Drains are ſeated in the cellular Membrane, from whence that Oil comes which is often diſcharged in the Urine after violent Exerciſes of Body: which Contrivance was neceſſary, that the ſenſible Membranes of the Ureter, lubricated by the oily Mucus, might not be corroded or excited to Pain by the Acrimony of the Urine.

[5] From this Inflection of the Ureter it is, that the Pain ariſing from the Gravel is firſt perceived in the Loins, then in the Sides, and gradually more inward, till at length it is ſevere under the Pubes; then vaniſhes for a time, and afterwards produces a Stranguary. Namely, the firſt Pain is in the Kidney, the next in each of the Inflections of the Ureter, till the Calculus has ſlipped into the Bladder, and then the Pain ceaſes.

[6] Where the Peritonæum recedes from the Loins, and covers the Bladder, there the Ureter deſcends into this large Pelvis, conſtantly terminating in the lower lateral and poſterior Part of its Neck,

[7] Where-ever the Ureter becomes of a leſs Diameter, there the Stone will frequently heſitate and diſtend the Canal to the Thickneſs of an Egg, of which we have an Inſtance given us by *Nucke.*

[8] Here the muſcular Fibres become thicker than in other Parts of the Bladder, as *Euſtachius* has long ago repreſented, and as *De Graaf* has well deſcribed, inclining towards the Neck of the Bladder. Theſe being contracted whenever the Bladder is diſtended with a large Quantity of Urine, cloſe up the Mouth of the Ureter, and prevent any of the Urine from returning; and this they do more powerfully, as the Bladder is more diſtended. For there is not any Valve at the Entrance of the Ureter, as hath been formerly imagined; but the ſimple Mechaniſm here deſcribed anſwers that Intention, ſince there is always a greater Column preſſing upon the oblique Canal towards the Bladder, and but a ſmall Preſſure from the Bladder; and therefore the Urine is eaſily excluded from returning into the Ureter.

[9] The Urine now enters a large Receptacle, and this with conſiderable Advantage to the human Species, who being deſigned for a ſociable Life and various Employments, as well as to ſtudy and Meditation, thus avoid the Detriment which would have enſued from a perpetual Diſcharge of this Excrement. But then with this Advantage there follows great Danger of breeding the Stone, ſince the Urine cannot ſtagnate long in any Part, without giving an Opportunity to ſome of its groſſeſt Particles to be depoſited, which may lay the Baſis of a future Stone.

§. 358. The Truth of all this Doctrine is demonſtrated by the Microſcope, *Injections* [1], *Liga-*

Ligatures [2], the comparative Anatomy of theſe Parts in *Hedgehogs* [3], Dormice, Tortoiſes, Bears, Oxen, Birds, and human Fœtus's, as alſo the Diſſection of human Bodies, who have been obnoxious to Diſeaſes of the Kidneys, or to monſtrous and preternatural Diſpoſitions of them.

[1] *Malpighi* injected the emulgent Artery with Ink, which Liquor, as alſo the melted ceraceous Injection, we at preſent know by Experiment will return from the Artery through the renal Vein, and alſo into the Ureter. If the emulgent Vein be firſt tied, and the Kidney ſo adapted in an exhauſted Receiver, that only its Artery can communicate with the Atmoſphere, the Preſſure of the Air will then force Water through the immerged Artery into the Ureter, and by that into the exhauſted Receiver. *Drelincourt* having tied the Pelvis, blowed Air into the Arteries, which penetrated into the uriniferous Ducts.

[2] If a Ligature be made upon the Ureter in a living Animal, nothing will paſs into the Bladder, but that Part of the Ureter betwixt the Kidney and the Ligature will be wonderfully diſtended; or if you tie the emulgent Artery, there will be alſo no Urine diſcharged.

[3] I include the Hedgehog of both Kinds, as well the *Indian* called the Porcupine, as the *European*, which Animals have a kind of Thorns and Spikes inſtead of Hair; but even the Kidneys appear ſtill more evidently compoſed of an Aſſemblage of diſtinct Glands than in theſe Animals, if we examine into the Tortoiſe.

§. 359. Hence we underſtand that the Separation of the Urine is mechanically performed by the *Force* [1] of the adjacent Heart and ſtrong Arteries, by which the watery Blood is urged through the innumerable Turnings and Windings of the Veſſels, by whoſe *Reſiſtance* [2], oppoſite Motions and Concuſſions, an intimate Mixture is firſt made, and at length the more *aqueous* [3] and excrementitious Parts are ſeparated, propelled forward, collected and diſcharged through Ducts a little ſmaller than the Blood-veſſels themſelves.

[1] To this add the Force of Reſpiration, which promotes the Secretion of the Urine by a continual Succuſſion of the Parts.

[2] The many Turnings, Windings or Arches and ſerpentine Courſes of the ſmalleſt Arteries, and the Aſſemblage of them into Heaps, was not ſo produced but for ſome End, namely, to prevent the Paſſage of thoſe Juices which ought not to enter the uriniferous Tubes. And from hence it is, with the Compactneſs of the Kidney, that only the Urine is permitted to flow through the ſecretory Ducts, while the Blood, Serum, Milk, *&c.* are retained. But ſometimes we ſee that all of them paſs the ſame way, as in a true Diabetes, but then there is a morbid Relaxation of the renal Ducts.

[3] The Blood of the renal Arteries carries all the Humours mix'd together, both Lymph, Chyle, the abſorbed Vapours, and all the more ſubtle Humours, without depoſiting any Part; and it is therefore repleniſhed with the Matter of Urine which conſiſts of watery Juices, which Juices are more fluid than either the Blood itſelf, its Serum or Milk; inſomuch that if there are any Humours more fluid than thoſe which compoſe the Urine, they muſt be quite inviſible.

§. 360. There is not therefore any Occaſion to account for this Secretion by ſuppoſing any *attractive* [1], *emulſive* [2], or the like Faculties in the Kidneys.

[1] In ſhort, the Nature of this Secretion conſiſts entirely in an expulſive Force; nor does Attraction ever duly ſeparate thoſe Parts which are excrementitious from the arterial Blood, and leave behind the Parts of the Humours which are uſeful and neceſſary for the Preſervation of the human Body.

[2] From this Faculty, which the Ancients ſuppoſed to reſide in the Kidneys, they denominated their Arteries and Veins Emulgents, as if the Urine was formed by milking or preſſing out that Humour from the Blood through the Branches of the Papillæ: But all theſe imaginary Faculties are only a Cloak for Ignorance.

§. 361. Nor is there any Occaſion to invoke an urinous *Ferment* [1], ſince there is neither *Place* [2], Cauſe, *Time* [3], *Matter* [4], nor any Effects or Mixture of any ſuch Ferment to be demonſtrated for making the Urine.

[1] Several Authors have ſuppoſed the Urine to be a Liquor of a particular Nature, which did not before exiſt in the Body, but is generated in the Kidneys, and diſcharged from the Bladder. They likewiſe add, that the Seat of this Ferment is in the Kidneys, and therefore the Kidneys always taſte of Urine after they have been boiled. But we are well aſſured that the Urine, which conſiſts of the watery, acrid, and excrementitious Parts of the Blood and Humours, exiſted and circulated in the

Blood long before it was from thence ſeparated. The Secretion of the Urine is therefore performed by a ſimple Appararus aſſiſted by the Impulſe of the Heart and Arteries; for if a Liquor be injected into the Arteries, barely the Preſſure of the Syringe will force it through the ſecretory Ducts into the Ureter, without making any conſiderable Alteration in it.

2 Such a Ferment cannot reſide in the Arteries, ſince no Humour reſides in them for any time, and the Blood continually paſſes through with a ſwift Motion: for in the Arteries the Blood as yet looks red, but in the Tubuli of *Bellini* it is become Urine. Nor can any ſuch Ferment be ſeated in the Veins which return their Blood to the Heart, nor yet in the large Pelvis of the Kidney, ſince in that the Urine is already perfectly ſeparated: not yet can a Ferment lodge in the glandular Bodies of *Malpighi*, which are but few; and more eſpecially ſince the greater Part of the Urine is diſtilled immediately from the Arteries, which are directly continued to the Veins. In ſhort, the Urine is continually poured from the Arteries into the Ureters, and by them conveyed into the Bladder, as any one may be convinced by an eaſy Experiment: for if all the Urine be evacuated from the Bladder, after a ſhort Interval one may diſcharge a few Drops more, which were ſeparated from the Blood in that ſhort time.

3 There is not any Ferment known, which operates immediately upon its Mixture without requiring ſome time to alter the Liquor with which it is mixed; but we have already obſerved, that the Blood does not make any Stay in the Kidneys, but, on the contrary, the Celerity of the arterial Blood in paſſing through the Kidneys, is confirmed by the conſtant and ſpeedy Diſcharge of watery Li-

quors by Urine ſoon after they have been drank. Do but conſider how many Pounds of mineral Waters are often drank for a Breakfaſt, and which are all again evacuated by Urine in about a couple of Hours time.

[4] No Ferment can be formed of the arterial Blood; for if it was contained in that, all the Viſcera would eaſily partake thereof. Nor can it be formed in the Kidney, which is ſo compact a Viſcus; notwithſtanding *Helmont* aſſerts, that there is a peculiar rank Taſte in the Kidneys after they have been boiled: for that diſagreeable Smell and Taſte lies in the Pelvis, and is there derived from the Urine altered by the Heat of the Body. Even if a Ferment was to be granted in the Kidneys, it could never be ſufficient to tinge the vaſt Quantity of Urine, which paſſes through the Kidneys during the Life of Man.

§. 362. And for the ſame Reaſons (§. 361.) we ought neither to have recourſe to any fuſing or *precipitating* [1] Virtue.

[1] The Chemiſt not content with the ſimple Fabric of the Parts, muſt have the Secretion of the Urine accounted for by ſome Operation better known to themſelves than to the Nature of the Animal: and therefore they ſuppoſe every animal Juice to be derived from another which is more groſs, and this in the manner of Precipitation, as when an Acid ſeparates the curdled Parts from the Serum of the Milk. They therefore ſuppoſe the Mixture of ſome certain Liquor with the Blood of the Kidneys, which cauſes a Separation of the more ſubtle from the more groſs Parts, namely, a Seperation of the Urine from the more thick Blood. Dr. *Willis* goes farther, and illuſtrates his Opinion

by an Example of medicated Salts, by whoſe Efficacy large Quantities of Urine are derived from the Kidneys. But to what purpoſe is it for us to loſe our time in ſearching into obſcure and precarious Notions, when the Fabric of the Parts are ſufficient to account for all the Appearances? Beſides this, what has been ſaid (§. 256.) concerning Ferments, will be of equal Force againſt Precipitations.

§. 363. It is alſo from hence evident, that what *Helmont* [1] has feigned ſo induſtriouſly with regard to liquid Dung or Scoria mixed in the Kidneys as a Preſervative againſt the Stone, muſt alſo fall to the Ground together with the preceeding Hypotheſis.

[1] *Helmont*, who was a Man of ſome Ingenuity, gives us his Opinion in a Treatiſe of the Stone, that he believed the Urine to be formed in the Kidneys of a Humour which was not before Urine, by the Mixture of a liquid Dung, which was derived from the adjacent Inteſtinum cœcum. And he there goes on in the following Method of reaſoning: That all the Urine of a calculous Patient is thin and clear, even though all the other Parts of his Body are in Health; and that therefore when the Urine is yellow, no Calculus is generated: but if by a chemical Analyſis you enquire into the Nature of the ſtony Matter which tinges the Urine of a yellow Colour, it will be found fœtid, and very much like the inteſtinal Fæces. Therefore, as the Fæces of the Inteſtines are putrified by ſomething lodged in the Cœcum, ſo the fœtid Matter of the Urine is conveyed from the ſame Fountain in the Cœcum into the Kidneys. But

this liquid Dung from the Cœcum is a Preſervative againſt the Stone, and therefore it ought to be rather increaſed or promoted than evacuated by the Phyſician. He then inſtances his Offa, which is a ſolid Body produced of two Liquors inſtantly upon Contact, namely, Spirit of Urine and Alcohol of Wine: and thus he imagines the Stone to be formed of Earth joined with a volatile urinous Spirit, which alſo volatilizes the Earth; but this liquid Dung was an Antidote to this Formation of the Stone. But this Doctrine needs no Argument to overthrow it, nor to demonſtrate its Folly and Precariouſneſs; nor is there any Duct in the human Body, whereby any ſuch liquid Dung can be conveyed from the Inteſtinum cœcum to the Kidneys.

§. 364. And it is alſo very evident, that all the Humours which are *thinner* 1 than the Urine, will readily paſs out this way through the uriniferous Ducts, if they are brought thither by the renal Arteries. From hence therefore we underſtand, that there muſt be ſome Cauſe which prevents them from flowing hither (§. 223, 224.); or if they are brought to theſe Ducts, great *Weakneſs* 2 muſt ſoon follow. Now the Glands which are called Renes ſuccenturiati, are *always* 3 lodged upon the upper Part of each Kidney, but diſtinctly ſeparated from thence by the intervening Fat; and as they lie contiguous to the Diaphragm, they are in ſome meaſure attached to it by the Blood-veſſels, which they from thence receive; and they are compreſſed betwixt that Muſcle and the Kidneys, being furniſhed with Arteries, and without any proper excretory Ducts of their own, they appear of the like Structure with the *Spleen* 4, and to be ſubject to the like Actions with the Spleen, pouring almoſt all their Blood conſtantly thro' their Veins into the Emulgents, they ſeem to perform ſomething upon the venal Blood, which has been deprived of its more fluid, watery, and ſaline Parts by the Separation of the Urine, ſo that they ſeem to contribute to the venal Blood of the Kidneys, the ſame which the Spleen does by mixing its Blood with that of the Vena Portæ; but poſſibly there may be ſome other Uſe of thoſe Glands, and yet that which is here aſſigned ſeems not unreaſonable, till we acquire more Light into this Matter. But if the new Obſervation of *Valſalva* 5 was true with reſpect to theſe Glands, it would follow that we muſt alter our Opinion, and ſuppoſe them formed as aſſiſting Organs to the Teſticles for the Separation of the Semen.

[1] That the Humour which paſſes through the Kidneys is extremely thin, is evident from the Compactneſs of that Viſcus, which is much firmer than that of any of the other Viſcera in the Body: Beſides which, it is evident from the Inſpection of the uriniferous Ducts, which can ſcarcely be perceived by the Eye, unleſs armed with a Microſcope. It is therefore from hence eaſy to underſtand, that no Humour can paſs through the Kidneys which is thicker than the Urine; but the Reaſon is more obſcure, why the thinner Humours are not diſcharged by theſe Ducts, eſpecially the

Spirits, unleſs it is becauſe the more compact and heavy Parts of the Blood are, by the Laws of Hydraulics carried downward, while the more light and ſpirituous Parts aſcend into the ſuperior Branches of the Aorta: and from that Law of Hydraulics by which the moſt ſolid Particles moving among others which are leſs ſolid, will continue on more in a right Line according to the Direction of their Motion; but that Direction in a ſtraight Line is from the Heart towards the Head, and therefore the Blood which deſcends towards the Kidneys ought to be leſs ſolid, and compoſed of leſs moveable Particles; but ſo often as the Spirits and more ſubtle Juices are drove to the Mouths of the uriniferous Tubes, there is no doubt but they will paſs through into the Pelvis and Ureter.

[2] A Diabetes is a more frequent and copious Diſcharge of a watery or pale colour'd Urine than is uſual in a healthy State; the Urine appearing not ſalt but ſweet, white and thick, as if charged with a great Part of the Chyle. This Diſorder is the Conſequence of a Laxity in the uriniferous Ducts, which is a very uſeful Circumſtance for preventing the Gravel; but then by endeavouring to avoid the Gravel by perpetually drinking large Quantities of diuretic and diluent Liquors, the moſt uſeful and nutritious Part of the Humours are waſhed away, and an Atrophe and Death itſelf are at length brought on. There are other Patients who are alſo ſubject to plentiful Diſcharges of a watry Urine from a different Cauſe, namely, in hyſteric and hypochondriacal Diſorders; but theſe laſt copious Diſcharges of Urine do not come under the Denomination of a Diabetes. But theſe Patients certainly diſcharge their Spirits together with the Urine which appears ſo watery, and therefore in *England* it is properly denominated a

Lowneſs of Spirits. And this happens to hypochondriacal People, who vex themſelves in the Night with troubleſome Thoughts, or throw themſelves into a Rage with ſudden Anger; but ſo ſoon as the Urine begins to look yellow, they always find themſelves better.

[3] *Euſtachius* has given us many Figures of the Kidneys which appear ſo very different, that no two of them are in all reſpects alike; but yet he has never omitted the Glandulæ Succenturiatæ connected to the Diaphragm, and continually agitated by its Motions.

[4] For like the Spleen they appear of a black Colour, of a ſpungy cellular Fabric, being alſo deſtitute of any excretory Duct, unleſs the Vein performs that Office. But their Uſe is alſo the ſame of that with the Spleen, if what many have ſuſpected be true, namely, that the Blood is poured out into the cellular Fabric of theſe Glands, and after ſuffering the Action of Reſpiration or Preſſure of the Diaphragm, paſſes immediately into the Vena Cava or into the adjacent Vena Azygos without making any Secretion, and this in order to attenuate the venal Blood: at leaſt it is certain that the Blood returning from the Kidney ſtands much in need of ſome ſuch Aſſiſtance, ſince it has been deprived of its more fluid and moveable Particles, and is therefore more thick and ſluggiſh.

[5] This Anatomiſt perceiving Death approach called a Notary with Witneſſes, together with ſeveral Phyſicians, and other learned Men, before whom he conſigned over his Commentaries, deſcribing a Duct which deſcended from theſe Glands to the ſeminal Veſicles. Theſe poſthumous Obſervations with other Experiments of *Valſalva* were afterwards made public by *Morgagni*, as he acquainted me by a Letter in the Year 1720. Whatever

there may be in this Obſervation, it is no difficult Matter to determine by Experiment, if the Vena Cava be tied above at the Heart, and below at the iliac Veſſels, and then by exquiſitely filling the emulgent Arteries with ſome coloured Injection, and making a ſtrict Scrutiny whether any Duct remains after this Adminiſtration. But we have not been ſince able by this or any other Artifice, to diſcover any other Duct leading from theſe Glands, beſides a ſmall Nerve or an Artery, which deſcend parallel to the Spermatics from theſe Glands down to the Epididymis: and we know that in all Animals the ſpermatic Veſſels ariſe near the Kidneys and atrabiliary Capſules in both Sexes; and from hence aroſe the *Aſiatic* Phraſe, for Children to come from the Loins of their Parents, *Heb.* vii. 10.

§. 365. It is alſo from hence evident, that the Urine never ceaſes to be ſecerned from the Blood, but continually flowing through the Kidneys, is one of the principal Cauſes of the Secretion itſelf; alſo preventing the Ureters from *collapſing* [1], being obſtructed, compreſſed or concreting together, by which many other Diſorders of the Kindneys are avoided.

[1] This Diſorder may eaſily happen in the Tubes of *Bellini*, which are extremely narrow, and placed without the Power of the circulating Blood, as alſo in the Ureters and Pelvis from the Glue with which they are perpetually lined; therefore to prevent them from collapſing or concreting by being ſtuffed up with Matter, Nature has cauſed the Urine to be perpetually diſtilling through them. *Drelincourt* having faſtened a Bottle to the Ureter of a living Dog, obſerved that Drops of Urine

continually diſtilled into the Veſſel. But to prevent a continual Flux which would be ſo highly detrimental to the Animal, Nature has furniſhed a larger Receptacle, in which the Urine ſtagnating and parting with its more aqueous and fluid Humour, acquires a greater Diſpoſition to breed the Stone, as well in the Kidneys as in the Bladder, when Exerciſe of Body is neglected. Hence fat People are frequently troubled with the Stone. In the Overſeer of the new Church of *Leyden*, who was a very fat Man, one of the Kidneys was filled with a continued Maſs of Stone as large as the Kidney itſelf, while the Viſcera were buried in Fat. The Urine indeed contains in itſelf not only the Matter of a Calculus, but even the Urine of the moſt healthy Perſon is diſcharged full of true Calculi ſwimming in it, as I have frequently ſeen by viewing in a capillary Tube by the Microſcope, and I have often made artificial Calculi of the ſabulous Particles floating in it. In ſhort, the true preſervative Remedy againſt the Stone is not to be ſought for among the Arcana of the Chemiſts, but is to be expected only from Exerciſe with plentiful drinking of thin Liquors. If a Perſon who knows himſelf liable to the Gravel exerciſes moderately before Breakfaſt after drinking a Draught or two of pure Water, it will go a great way towards preventing the incipient Diſorder. But nothing injures the Kidneys more than the Abuſe of warm watery Liquors drank too plentifully or too hot, and joined with Idleneſs or a ſedentary Life; for thus is produced a Laxity of the renal Arteries, which gives the Blood an Opportunity to miſtake its Courſe; and when once any of the red Parts of the Blood have enter'd the uriniferous Tubuli, they lay a ſure Baſis for a Calculus. Thus *Fernelius* has long ago obſerved, that there is a red

Nucleus always found in the middle of urinous Calcúli; and *Helmont* wiſely obſerves, that a Firmneſs or compact Texture of the Kidneys, is one of the ſafeſt Preſervatives againſt the Stone.

Of the Structure and Action of the Urinary Bladder.

§. 366. THE urinary Bladder is ſeated in the Pelvis under the Lamella of the Peritonæum; which is expanded above it, and being ſecurely *defended* 1 by the ſeveral Bones, it appears to be made of three diſtinct Membranes, namely, the *external* 2 from the Peritonæum, the middle one conſiſting of various *muſculous* 3 Fibres, and the internal Tunic furniſhed with *mucous* 4 Glands, which prevent this membranous Receptacle from being eroded by the *acrid* 5 and ſtagnating Urine. A great Number of Blood-veſſels are alſo diſtributed throughout the Membranes of this Receptacle, in a particular Courſe or Direction different from that in which the Veſſels run either in the Skin, Kidneys, Spleen, Liver, or any other Part. When therefore the Urine excites a painful or an uneaſy Senſation by its Acrimony, Quantity, or long Retention, by which it erodes, diſtends or irritates the contiguous Membranes, by *abrading* 6 their Mucus; that uneaſy Senſation excites the Motion

of

of the ſeveral Parts which we before explained, (§. 111.) whereby all the Contents of the Abdomen are urged or preſſed with a conſiderable *Force* 7, returned by the Lamella of the Peritonæum extended over the Pelvis upon the Bladder itſelf; which meeting with leſs Reſiſtance in its lower Part at that time, the Urine is therefore expelled downward with a conſiderable Force, and through the Opening or Neck of the Bladder which it extends, preſſes the circumjacent Veſſels, and *overcomes* [8] the Reſiſtance of the orbicular or arched Sphincter; which Sphincter is ſeated in the upper Part of the Neck of the Bladder above the proſtate Gland, under the external longitudinal Fibres of the muſcular Coat of the Bladder, the tranſverſe fleſhy Fibres of this Sphincter being not very thick: by this Force therefore the Urine is drove into the Cavity of the Urethra, lubricated and defended with an oily ſoft Mucus, which always flows plentifully from the Ducts of *Cowper* 9 and *Morgagni*; which Urethra deſcending from the Bladder in a winding Courſe, riſes up again in a Curve, and then deſcends, being of different *Diameters* [10] or Capacities in different Parts of its Courſe, and inveſted all the way with a cavernous and *ſpongy* [11] Duct, through which it paſſes; ſo that the Urethra being flaccid at the time of this Action (§. 111.), the Urine is evacuated through it from the Body.

[1] The Pelvis is the fourth remarkable Cavity of the Trunk, comprehended betwixt the Os ſacrum

and Coccyx behind, before by the Os pubis, and laterally by the Oſſa ilia, being partitioned off above from the Abdomen by the Peritonæum, nor is it compreſſed by any of the abdominal Muſcles. In the Cavity of this Pelvis are placed the Inteſtinum Rectum and Bladder, and the Uterus in Women. But all the Viſcera ſeated in the Pelvis ſuffer a Compreſſion from the Diaphragm and abdominal Muſcles, by which the abdominal Viſcera being preſſed downward, communicate the ſame Preſſure to the Viſcera of the Pelvis, and eſpecially to the diſtended Bladder, which finding a leſs Reſiſtance in the Urethra than in any other Point, the Urine can only flow out that way. How conſiderable is the Force of this Preſſure exerted in the Pelvis, may appear from the Endeavours of Women in Labour; but the Bladder is preſſed equally with the ſame Force as the Uterus; ſince the abdominal Viſcera deſcending are urged againſt the Bladder, or rather againſt the convex Part of the Peritonæum with which it is covered, while the Peritonæum at the ſame time riſes up with the Bladder and forms a Concavity. But the Peritonæum does not contain or inveſt the Bladder, covering only its Fundus or upper Part, which ought to be particularly obſerved in performing the high Operation of the Stone, according to *Peter Francus*, namely, by diſtending the Bladder ſo as to make it riſe up in the Cavity of the Abdomen, whereas when it is empty, it deſerts the Abdomen and contracts itſelf down to the Bottom of the Pelvis.

[2] There are two Lamellæ of the Peritonæum, namely, the Peritonæum properly ſo called, and the cellular Membrane which lies on the Outſide of it; but it is the latter only which inveſts the whole Bladder, and the Peritonæum ſtrictly ſpeak-

ing only covers the Fundus or upper Part of the Bladder, as we obſerved before.

[3] Anatomiſts uſually aſcribe a ſingle Strata of Fibres in the Bladder, continued longitudinally from the Fundus to its Neck or Sphincter, by which it is ſuppoſed to antagonize or contract itſelf again. But this is not ſufficient to explain the beautiful Fabric of this muſcular Receptacle. For the Bladder in a healthy Perſon is required to be ſo diſtenſible, as to contain ſix, eight, ten, or more Ounces of Water; and again to be capable of contracting itſelf, ſo as to be ſcarce capable of receiving a Filberd-nut: and in this Variation it is neceſſary for the Bladder to continue changing its Figure and Capacity every Moment by the diſtending Power of the Urine, and the contractile Force of its muſcular Fabric. To effect this, Nature has ſupplied the Bladder with many Radii or muſcular Fibres, extending themſelves in all Directions throughout the Bladder. Even *Euſtachius* has repreſented ſomething of this Fabric in the Figure of the Bladder, which has not been obſerved by his Interpreters. *Ruyſch* tells us, that the Diſtribution of the Veſſels in the Coats of the Bladder, is very different from their Courſe in any other Part of the Body; and the ſame Anatomiſt alſo demonſtrated the various muſcular Radii or Interſections of Fibres in this Part, even before the anatomical Tables of *Euſtachius* were found. There is alſo ſomething of the ſame Fabric in the Membrane of the Tympanum, where the Fibres and Arteries are diſtributed from the Center towards the Circumference; becauſe it is required to be capable of various Degrees of Tenſion and Relaxation like the Bladder. How conſiderable a Force is exerted by this Contraction of the Bladder, may appear from ſome Experiments which are made on Dogs

and Cats, as alſo from too long a Retention of the Urine in thoſe who are accuſtomed to be over modeſt. In a Dog who retained his Urine three Days by a Ligature, upon turning him looſe no Evacuation followed; I therefore made a ſmall Wound through the Bladder, and the Urine flew up to a conſiderable Height, the Bladder itſelf contracting to ſuch a degree, that there was ſcarce the leaſt Cavity remained.

[4] The Innocency of this Mucus was firſt demonſtrated in Oppoſition to the Schools by *Helmont*, who aſſerted that it did not afford the Matter of the Stone, but was formed for lubricating the Parts, and eaſing the Pains; ſince the Mucus arrives more plentifully, as the Stone is larger and more rough, and irritating to the Bladder, in the ſame manner as provident Nature ſupplies Tears to the Eyes, to waſh off any contiguous Matter. In ſhort, there are ſome Inſtances where eight Ounces of this Mucus has been evacuated in a Day.

[5] How intolerable the Pain is, ariſing from the Acrimony and Retention of the Urine, thoſe are well acquainted, who through Modeſty have ſometimes retained their Urine long beyond the ſeaſonable time. *Tiberius*, who was a Tyrant not of the common Stamp, and extremely ingenious in torturing his Enemies, tied up the Urethra in thoſe whom he hated moſt, after firſt obliging them to drink a large Quantity of Water.

[6] If the leaſt Part of the Bladder is deprived of this Mucus, a Strangury follows, namely, as ſoon as a Drop of the Urine touches the ſenſible or nervous Fibres, which are not cloathed with their Mucus, an irreſiſtible Inclination for voiding the Urine follows, which cannot be governed by any Influence of the Will, but the offending Drops of

Urine are immediately diſcharged with all the Efforts of Reſpiration.

[7] This Force is not neceſſary, if there are but a few Drops of Urine, for then they may be diſcharged almoſt ſpontaneouſly; but if the Bladder is extremely full, the Urine cannot be voided until a few Drops are firſt expreſſed with a conſiderable Force, and then the reſt of the Urine follows almoſt ſpontaneouſly.

[8] The Sphincter Muſcle cloſes the Neck of the Bladder ſo firmly, that notwithſtanding there is a free Paſſage almoſt ſufficient to admit the Finger, and ſometimes even to diſcharge Stones that are much larger, when the Bladder is full, and the Parts lubricated with Mucus; yet ſo great is the Contraction in a natural State, that not the leaſt Drop of the Urine can eſcape, until ſome Part of it is forced out by the Contraction of the Diaphragm and abdominal Muſcles: and then, as Water flowing from a larger to a narrower Receptacle, preſſes the coverging Sides with a conſiderable Force, the Nerves of the Sphincter will be thus compreſſed, overcome, and relaxed, ſo that all the remaining Urine will meet with an eaſy Paſſage with little or no Force to urge it, and yet does the Urine flow out with ſuch an Impetus, as ſometimes to throw out a Stone againſt the Wall with ſuch a Noiſe, as if it was diſcharged by a Machine. It is a Piece of good Advice for thoſe People who are afflicted with a Calculus lodged in the Orifice of the Urethra, to retain their Urine as long as they are able, and then of a ſudden to uſe all their Endeavours to diſcharge it at one Inſtant, by which means Stones of a very large Size have been often diſcharged. Hence therefore a Fœtus cannot diſcharge any Urine before it has breathed (§. 684.) So exquiſite a Guard has Nature pla-

ced upon this Part, though framed of ſuch ſoft and tender Materials, that the utmoſt Art of Mechanicks can ſcarce produce the ſame Mechaniſm by the working up of Metals.

[10] The Urethra paſſing out of the Bladder is at firſt very narrow, and from thence to the ejaculatory Muſcles, into which Part the Semen is poured, it is the largeſt of all, being denominated in this place the Bulb of the Urethra. In the ſecond place, it is contracted from the Inſertion of the ſuſpenſory Ligament where the Penis is inflected, and from thence goes on cylindrically, keeping the ſame Diameter, till it at length dilates again in the Glans, and at laſt converges at its Termination in the Extremity of the Glans, which makes the third and laſt Stricture. There are therefore three Dilatations and as many Strictures in the Urethra, at all which laſt a Calculus may ſtop and torture the Patient. In Women the Urethra is very ſhort, and has but one Stricture. In thoſe lamentable Caſes, where a Calculus ſtops at any of the aforementioned Strictures in the male Urethra, one of the beſt Remedies is to inject Oil of ſweet Almonds, and then to thruſt forward the Stone through the Paſſage which has been lubricated by the Oil. The ancient *Egyptians* had a Method of diſcharging a Calculus in the Urethra by inflating and diſtending that Canal in the Penis, ſo as that the Calculus might be drove forward by the Fingers; which is certainly one of the beſt Methods, provided the Urethra has been firſt lubricated with Oil.

[11] This Mucus is extremely neceſſary for preventing the Sides of the Urethra from collapſing or adhering in the time of Sleep, or whenever the Urine has been retained for a long time; which deplorable Diſorder I have ſometimes ſeen accom-

panied with the moſt ſevere Pain: it is ſeparated by the ſolitary Glands of *Cowper*, which he diſcover'd. As alſo in the pendulous Part of the Urethra, it is diſcharged by numerous Follicles or Drains, obſerved by *Morgagni* and *Fantoni*, unleſs any one chuſes to call them by a different Name.

[12] All the Parts which are here mention'd deſerve our ſtricteſt Attention, more eſpecially the Ducts of *Cowper*, in which a Gonorrhæa of a long ſtanding uſually fixes its Seat, at leaſt in our Times. An Ulceration of the Subſtance of theſe Glands occaſions a moſt obſtinate internal Gonorrhæa, in which Fiſtulæ ariſe diſcharging a contagious Matter.

§. 367. So ſoon as *this* [1] Action (§. 366.) ceaſes, the Fibres of the *Sphincter* [2] Muſcle contract themſelves by their natural Force, as being no longer compreſſed; by which means the Neck of the Bladder is cloſe ſhut, and then the Muſcles which ejaculate the Urine in Men preſs out what remains in the Urethra: for as theſe Muſcles ariſe from the upper and external Part of the Urethra under the Os Pubis, where their Tendons departing from each other are inſerted into the cavernous Bodies of the Penis, and inveſt that Part of the Urethra, which coming out from the Bladder is the largeſt of all, and inveſted with its proper cavernous Body; while the Corpora cavernoſa of the Penis have not as yet united together externally: here theſe Muſcles uniting below, go on to the Peritonæum, where they ſeem to become tendinous, and to combine ſtrongly ly in a manner with the tranſverſe Muſcles of the Penis, fixing themſelves into the Root or Bulb of the Urethra; from whence one may eaſily underſtand their *Action* 3, which being aboliſhed in *old Men* 4, they are troubled with a dripping after making Water, and a ſharp corroding Pain follows from the retained Urine.

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[1] This is alſo accompanied with the muſcular Contraction of the Bladder itſelf, by which it is reduced from a large Capacity to a ſmall Globe, ſo as to evacuate all its contained Urine into the Urethra.

[2] So ſoon as the Urine is forced out through the Mouth of the Urethra, no Cauſe then remains to compreſs and relax the Sphincter: nor has this Muſcle any Antagoniſt at that time; and therefore the Sphincter recovering itſelf, ſhuts cloſe the Neck of the Bladder as at firſt.

[3] Which Action is to conſtringe the back Part of the Urethra, ſo as to protrude both the Urine and the Semen out of that Canal; the laſt of which is poured into the Urethra through the Mouths or Eyes of the Caput Gallinaginis. To this Action alſo add the ſingle Muſcle of M. *Littre*, which is placed betwixt the Bulb of the Urethra, and the Sphincter ani.

[4] The ejaculatory Muſcles which throw out the Urine, are always ſtronger in proportion as the Perſon is younger; whereas in old Age they become almoſt paralytic, whence their Impotency. And the ſame holds true with reſpect to the Penis in all other Animals. Hence in young Men the Urine is diſcharged in a full Stream to a conſiderable Diſtance; but in old Men it is thrown to a very

ry ſmall Diſtance, and in a broken Stream. There are alſo many Drops of the Urine which remain in the Bulb of the Urethra before it enters betwixt the Bodies of the Corpora cavernoſa; and this Urine being retained for want of Strength in the Accelerator Muſcles ſtagnates, becomes acrimonious, and excites an incurable painful Strangury, as *Hippocrates* formerly obſerved, to be relieved by no oily Medicines. In that Caſe the only Relief that remains, is for the Patient to ſqueeze forward the remaining Drops of Urine from the back Part of the Urethra with his Hand or Fingers: for by this means imitating Nature, ten or twelve Drops of Urine are expreſſed, which if retained would have occaſioned great Uneaſineſs. And in this we have a notable Inſtance how eaſily a Diſorder may be cured, when we are acquainted with itis Nature and Cauſe.

§. 368. But the Urine itſelf is of ſo *many* [1] Sorts, that we ought firſt to diſtinguiſh them before we can ſay any thing juſtly concerning its Nature.

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[1] *Paracelſus*, in his rough and obſcure Diction, was the firſt who with Judgment propoſed this Diſtinction. In general, we call the Urine all that Liquor which is evacuated from the Urethra of a healthy Perſon, except only the Semen and its mucous Vehicle, which naturally lubricates the Urethra. But although the Urine is properly an Excrement, yet the Conſideration of it is extremely neceſſary to a Phyſician, who ought to conſider it almoſt in every Diſeaſe, as a Meſſenger relating to him what is ſuffered by the Blood within the Veſſels.

§. 369. For after plentiful *drinking* [1] of watery Liquors, the Urine is crude, much in Quantity, mild or inſipid, inodorous and almoſt without Colour, of a watery Nature, and may be retained in the Bladder without Uneaſineſs.

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[1] *Paracelſus* calls the Urine Drink, evacuated in proportion to the Quantity of Liquor taken into the Stomach, of a watery Conſiſtence, inſipid, and almoſt inodorous. I have repeated ſeveral Experiments both on myſelf and Friends in reſpect to the Urine. If a healthy Perſon makes Water while faſting, and ſo ſoon as out of Bed, the Urine appears concocted, has a Smell, a bitter Saltneſs, and a high yellow Colour: if now the Perſon drinks half a Pint of warm Spring-water, he will in a quarter of an Hour's time diſcharge Urine almoſt inodorous, and more nearly reſembling Water; if again after this as much more warm Water be drank, the Urine will be voided almoſt without Colour or Smell, and without any Sediment. If thus Water is continued to be drank in this manner, as I have ſometimes done myſelf ten times, at laſt the Water will be diſcharged little or nothing alter'd, flowing from the Bladder as through a Funnel, and with ſo great an Inclination to Excretion, as will ſcarce permit the Mind to influence the retentive Organs. From this Experiment it appears, that ſo much Water may be taken into the Body, as will produce a continual Succeſſion of Liquor flowing from the Stomach through all the Veſſels in one continued Thread to the Bladder; and that at length becoming gradually thinner, it is at laſt voided almoſt crude, with little or no oily or

ſaline Parts, ſo that by this means all the ſtony Matter may be waſhed out from the Blood. Even a conſiderable time after I had left off drinking the Water, the Urine continued very watery and limpid for a conſiderable time, and therefore a Phyſician can conclude nothing from ſuch Urine as we have here deſcribed.

§. 370. But the Urine which is voided after the *Chyle* [1] is formed, appears more concocted, leſs in Quantity, more acrid, ſaline, a little fœtid, of a light yellow, or pale ſulphur Colour, being not ſo eaſy retained in the Bladder.

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[1] Another Species of Urine according to *Paracelſus* is that of the Chyle. The Chyle is not immediately converted into Blood after entering the Veins, but it circulates together with the Blood, and is continually ſupplied with more Chyle for above eight Hours after a Meal, according to *Lower* and *Wallis*, allowing an Hour or two Variation for the Difference of Strength in the digeſtive Organs of different People. Even after the Chyle has been changed into Milk, it circulates with the Blood under that Form for the Space of twelve Hours before it is turned into Serum. I knew a Nurſe who was ſupplied with good Milk in her Breaſts, even twelve Hours after ſhe had eat any thing, and without drinking in the mean time, the Milk flowing freſh from the Arteries into the lactiferous Ducts of the Nipple; but this is not often to be met with. But if the Milk is confined a longer Time in the Body, it turns yellow, grows bitter, and is refuſed by the Infant, for in that Time it begins to change into the Serum of the Blood. As

long as the Chyle is not yet converted into Blood, the Urine which is then avoided, is by *Paracelſus* termed the Urine of the Chyle, and it then in a great meaſure retains ſomething of the Nature of the Food or Aliment which the Perſon took laſt: for by Aliments only we may make or imitate all the Kinds of Urine, which are obſerved in acute Diſeaſes. The eating of Rhubarb and Saffron renders the Urine like that of an ardent Fever, and Tamarinds turn the Urine green; whereas Caſſia and Aſparagus make it black and fœtid, like the Urine which is voided after a Gangrene in ſome of the internal Parts. The Urine which is rendered ſome time after a plentiful Uſe of Oil of Almonds, determined towards the Kidneys by Caſſia, looks purulent, as if it contained Matter. From hence we conclude, that neither this Urine of the Chyle is to be truſted as a faithful Meſſenger indicating the State of the Blood.

§. 371. But *again* [1] the Urine which is diſcharged after the Chyle has been converted into Serum, appears more of a yellow or ſtraw Colour, more concocted, reddiſh, ſmall in Quantity, ſaline, fœtid, acrid, and very ſtimulating, inſomuch that it cannot be long retained in the Bladder.

[1] That Urine which is diſcharged about twelve Hours after a Meal, (by which time the Milk of the Chyle turns into Serum of the Blood—according to the Obſervation of *Lower*, being derived from the yellow Serum) is doubtleſs a more faithful Witneſs, and indicates more of the Nature of the Blood than any other Urine; it is acrid and cannot be long retained becauſe it ſtimulates the Bladder to Excretion.

§. 372. But finally, the Urine which is made after *long* [1] faſting, when no Drink has been taken for a conſiderable time, is derived from the Humours which have been a long time powerfully *rubbed together* [2], and alſo from the ſolid Parts which have been broke off by the ſame Attrition; and this laſt mentioned Urine is the ſmalleſt in Quantity, very ſharp, *ſaline* [3], fœtid, very red, and ſcarce retainable in the Bladder, it is alſo found very much inclined to Putrefaction.

[1] If the moſt healthy Perſon gives himſelf up to Sleep after Supper, without drinking all Night, and without taking any Breakfaſt in the Morning, he will void the Urine which was collected over Night, but the next Urine which he voids immediately after, will be more fœtid, bitter and high coloured, containing generally more of the calculous Matter, and at length by long Abſtinence only, inflicted either by Poverty or ſome religious Command, the Urine becomes ſo acrimonious after twenty-four Hours as to produce a Strangury. Hunger hardly kills of itſelf, until it has been continued for a long time; a Perſon may ſupport Life with mere Water for twenty Days without taking any Food; for Water will waſh out the acrid Parts of the Blood, which being retained would deſtroy the Brain; and therefore thoſe who periſh with Hunger do not expire ſo much for want of Aliment as for want of waſhing out the Acrimony of the Humours which Abſtinence creates. When *Charles* V. carried on a War in the ſcorching Regions of *Africa*, a great Number of his Soldies periſhed daily, till at length the Scarcity of Water

performed more than the Arms of the Enemy were capable of; for Soldiers ſoon periſh if they are deſtitute of Water. We read formerly that *Jacob* and *Eſau*, two Brothers, accompanying each other in their Journey, ſaid one to the other from Experience, that if the Flock was to be tired by driving even half a Day in the hot Sun they would periſh. For barely by the vital Heat and Attrition, the unctuous Humours which defend our Veſſels, with the Mucus of the urinary Paſſages are quite deſtroyed, the oily Parts of the Blood turn rank, the Saliva and Bile acquire a corroſive Nature, the Urine becomes quite alcaline, and the Salts of the Blood itſelf become acrid or alcaline from their natural State, as *Tſchirnhauſen* has formerly demonſtrated.

[2] All this happens in a little time in acute Diſeaſes. For the Heat and Attrition of the Humours are very intenſe, ſo as to render the Urine ardent or ſcalding as it is termed, of a flame Colour, very acrid, fœtid and full of Scales or Fleeces of Mucus, obliging the Patient to evacuate it almoſt every Moment, as *Hippocrates* formerly obſerved: hereupon the Appetite to Food ceaſes, a Nauſea and Vomiting follow, and in the moſt acute Diſeaſes a Quinſy and Hydrophobia; in which, Water itſelf is abhorred, or any other Drink. But the common Cauſe of all theſe Phænomena, is that Acrimony and Alteration of the Humours which we before deſcribed.

[3] The natural Salts of the human Body approach the Nature of Sal Ammoniacum, and no wonder, ſince Sal Ammoniacum is compoſed of Urine or Dung with the Addition of Sea Salt.

§. 373. From hence therefore we may be able to anſwer, why Urine is diſcharged (like that at §. 372.) after great Heat, violent Exerciſe, profuſe Sweating, or Abſtinence from Drink? And alſo why the Urine appears the Reverſe under oppoſite Circumſtances?

§. 374. Why the Urine appears thinner, more *acrid* [1], *fœtid* [2] and *ſaline* [3] than the Blood itſelf?

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[1] If we enquire after the final Reaſon why the Urine is ſo acrid, the following may be given. As the Creator made Man an active Animal to be continually in Exerciſe, and at the ſame time to laſt or ſurvive for many Years, ſince there is no Animal that eaſily outlives Man; and there are ſome Men who live to a hundred and fifty Years of Age, which can be ſaid of no other Animal. But in the continual Exerciſes and Motions of Life, our Humours do by unavoidable Neceſſity become attenuated ſo as to exhale, whence Supplies of new Matter to the Body become neceſſary, that is, from the Aliments which in general are taken either from Vegetables or Animals. But all Plants, and much more all Animals, do by a Heat equal to that of the human Body, putrefy in eleven or twelve Days time, and turn into a moſt fœtid Excrement. If ſuch a Change was to be made in the conſtituent Parts of our Bodies, and the acrid Humours were not to be diſcharged before they were perfectly corrupted, our tender Machines would ſoon be deſtroy'd. There are therefore Ciſterns and Receptacles in the human Body, wherein to depoſit thoſe Parts of our Humours which are become acrid and nearly inclined to Putrefaction,

that they may be at length diſcharged from the Body, as a foul and pernicious Matter. Of this nature are the Kidneys and Bladder, together with the Liquor which waſhes out the putrid and lixivial Parts of the Blood and Humours, which we call by the name of Urine. The Neceſſity of drinking never leaves us, ſo long as any Salts remain unſheath'd in the Body. But the Excretion of the Urine is ſo neceſſary, that a Retention of it for twelve or fourteen Days has proved quite deſtructive to Life: not from a Retention of the Drink diſtending the Veſſels and Viſcera, for that might have been remedied by Abſtinence: nor yet becauſe the Quantity of the Blood was too much increaſed by the continual Addition of new Chyle; which Diſorder might have been remedied by bleeding and purging; therefore the only Cauſe of Death is the acrid Lixivium of the Urine retained in the Blood, and deſtroying the tender Fabric of the Brain. Hence it is that before Death in thoſe who periſh by a Suppreſſion of Urine, the Functions of the Brain are always diſturbed, and Death itſelf is brought on by an Apoplexy: for the oily Parts of the Urine being continually fomented by Heat and Attrition, acquire an incorrigible Acrimony.

[2] All fœtid Smells ariſe from Oil, as we are taught by Chemiſtry. But Oil which is thick and ſolid like Fat, is not at all fœtid; whereas if it be attenuated by Heat and Attrition, it becomes yellow, acrid, and very fœtid. But of this nature is all the Oil contained in the Urine, which is become miſcible with Water, after being attenuated by a long Circulation through the Veſſels. But if Urine is diſcharged mild and ſweet, or milky, as in a Diabetes, Death is then near at hand.

[3] There is not any Humour in the whole Body, whoſe Saltneſs comes up to that of the Urine; the Chyle, Milk, Serum of the Blood, Blood itſelf, Mucus, Semen, *&c.* are all ſweet and inoffenſive. The Tears indeed are ſalt, though not immoderately ſo; but if they continue to flow over the Cheek for a long time together, they excoriate and excite an Inflammation in the Eyes and Skin. The Sweats which are forced out by hard Labour, indeed partake of Acrimony, but not ſo as to be injurious thereby. The Bile comes neareſt to the Urine in Strength of Acrimony, and yet it is much milder, as appears from the Bile not injuring the Eye when ſprinkled into it; for the Gall of an Eel is frequently applied to the Eyes with conſiderable Advantage, without cauſing any great Pain or Uneaſineſs, whereas Urine inflames the naked Eye. It is alſo demonſtrated from a chemical Analyſis, that there is no Humour in the Body which contains ſo large a Quantity of Salt, as the Urine affords by Diſtillation. For the Salts of the human Body do not naturally exiſt under the Shape of Salts, but they are drawn out, ſeparated, or made by Putrefactions, or an Attrition of the Humours.

§. 375. The Urine therefore contains not only the *watery* [1], but alſo the *ſaline* [2], *oily* [3] and *earthy* [4] Parts of the Blood; it contains thoſe Salts which are moſt acrid, ſubtilized, volatile, and nearly alcaline; it contains thoſe Oils which are moſt attenuated, volatilized, rancid or acrimonious, and nearly approaching to a State of Putrefaction; it contains alſo the Particles of Earth, which are extremely ſubtle, in a great meaſure volatile, and much divided by Attrition.

[1] The greateſt Part of the Urine is truly watery. and therefore the Urine waſhes out all thoſe oily, ſaline, and earthy Parts of the Blood, which would be injurious or deſtructive to the Body.

[2] We all abhor putrid or ſtinking Food; but it is to that State which all our Humours incline, unleſs the Urine waſhes out all the Salts before they become quite volatile: for in reality there is never any truly volatile Salt in any of the animal Humours; nor in the Urine itſelf is there ſo much as a ſingle Grain of volatile Salt to be found while in its natural State, as I have long ago demonſtrated; ſee Proceſs 92 and 94 of our Chemiſtry.

[3] All that gives Smell or Colour to the Urine is the Oil; for neither Salt nor Earth have a fœtid Smell, nor any Colour when they are pure. Nor is this at all wonderful; for the mildeſt Oil, even the Cream of Milk, which is ſo white, being fried in a Pan turns bitter, and acquires an empyreumatic Smell; and therefore the more the Oil is attenuated by Heat and Attrition, ſo much the redder and higher coloured will the Urine be, even down to Blackneſs.

[4] Few People would imagine, that a large Quantity of Earth lies concealed in the moſt limpid Urine: but this Truth was firſt diſcover'd by *Helmont*. He diſtilled Urine ſeveral times, till at the Approach of *Eaſter* he deſiſted in Reverence to the Time; but after the Expiration of three Days, he returned to work at his beloved Furnaces: he found that the Retort in which he had diſtilled the Urine, was incruſted on all ſides with a kind of Earth or tartarious Matter. Upon another time, after expoſing Urine to Putrefaction in

a gentle

a gentle Heat in a very tall glaſs Body, he exhaled a very limpid Water, which left behind a dry, ſimple, inſipid, and inodorous Earth; and therefore he concluded from theſe and other Experiments, that there was a very ſubtle and volatile Earth mixed with the Urine, capable of riſing into Vapours with a gentle Heat; and that this Earth, upon the Acceſſion of any coagulating Cauſe, produced the Stone. Even in the moſt ſubtle Spirit of Urine, as alſo in all Waters and Oils, there is an Earth concealed, though it is frequently difficult to ſeparate it. I myſelf ſet by ſome Spirits of Urine in Glaſſes very exactly cloſed, in which it ſtood for many Years, and at length it depoſited a white volatile Earth. But this is really a true Earth, dry, ſolid, and unchangeable, being thoſe Particles which compoſe the ſolid Baſis of all the Fibres and Veſſels in the Body, as I demonſtrated in the Year 1702. This Earth is the only Subſtance that remains after burning the Bodies of Animals, and being inſipid, white, and very fixed in the Fire, it affords the beſt Matter for making of Veſſels in which Silver is refined. The Glue which connects the Parts of this Earth is oily, which with an intenſe Fire partly exhales, and in part turns into Phoſphorus. This ſame Earth is tore off from the ſolid Fibres of the Body by the Impulſe of the circulating Humours, and returning into the Blood, it is carried into and diſcharged from the Kidneys by the Urine. There is therefore great Plenty of that Matter in the Urine, which is apt to form the Stone. And even the Stone itſelf is formed of the Matter of the ſmall Veſſels of the Body, which has been abraded by the Vis Vitæ, and depoſited through the Kidneys: and inſtead of that earthy Matter which is continually abraded, a new ſubtilized Earth is conſtantly ly ſupplied from the Aliments, to preſerve the Machine of the human Body from Diſſolution.

§. 376. But in the watery Part of the Urine there is a very ſubtle, volatile and fœtid *Oil* [1], altogether of a particular Odour, which ſtrongly adheres to the Water, being firſt ſo highly attenuated that it may be intimately mixed therewith, and can be afterwards very difficultly ſeparated; it may therefore perhaps be not improperly termed a Spirit?

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[1] The recent Urine which has been diſcharged ſome time after the Concoction of the Aliment has been performed ſmells fœtid; and if it be diſtilled over a hundred times, there will always remain ſomething fœtid. There is therefore an Oil in the Urine which manifeſts itſelf by no other Appearance than that of a fœtid Smell. If the Urine is permitted to ſtand at reſt, its fœtid Smell continually increaſes, and if the more fluid Parts of it are drawn over by Diſtillation, even that diſtilled Water of the Urine will be fœtid: But yet the Urine which is voided by thoſe who drink Plenty of Punch and Malt Liquor is deſtitute of this fœtid Smell. It may be therefore aſked, whether or no this fœtid Water may not paſs under the Denomination of a Spirit? For what are Spirits more than Oil attenuated and mixed with Water? But as for an inflammable Spirit, I could never obtain the leaſt Quantity even from above a hundred Pints of diſtilled Urine. Nor could I ever obſerve that Fermentation of the Urine which *Helmont* deſcribes, ſo as to burſt the Glaſſes by the ſpontaneous working of it; but perhaps *Helmont* might have repoſited his Urine in a Caſk in which Wine had for-

merly been contained, many Parts of which being abſorbed by the Wood might cauſe a Fermentation.

§. 377. The *natural Salt* [1] of the Urine is *ſaponaceous*[2], and nearly akin to *Sal Ammoniacum* [3], from which it differs notwithſtanding its Alcali being more eaſily ſeparable; it alſo contains ſome *fixed* [4] or Sea Salt, which is chiefly derived from the common Salt of our Aliments: therefore the Salt of the Urine is neither *acid* [5], *alcaline* [6], *muriatic* [7], nor ammoniacal, but of a peculiar Nature or Diſpoſition, being perfectly white when it is unmixed.

[1] A Salt may be prepared from the Urine of the human Body differing from all other Salts in the whole Field of Nature; and if any Salt deſerves the Title of eſſential, it is certainly this of the Urine: for an eſſential Salt is properly one obtained from the Juices of Vegetables by a Cryſtallization without the Force of Fire. But it is no wonder that ſuch a Salt ſhould be found in the Urine, ſince that and all the other Humours in the Body are prepared from Vegetables: but this Salt of the Urine is nevertheleſs very different from all others, which are obtained from any ſolid or fluid Parts of the human Body by Fire and Putrefaction; for thoſe Salts are alcaline and cauſtic, of which nature there are none naturally in the Humours of the Body. But the Salt we now ſpeak of as eſſential, is that which the Humours of a healthy Body have tranſfuſed or diſſolved in Water, which circulates together with the Humours, and paſſes afterwards together with its Salts through the Kidneys without any Alteration, excepting only that it is deprived

of its Water by Inſpiſſation. Nor is there any Humour of the Body, however inſipid, but what contains a Salt of this nature.

[2] Compoſed of an Oil and lixivious Salt miſcible with Water; ſuch a Salt is ſaponaceous: but of this nature is the eſſential Salt of the Urine compoſed of an attenuated Oil mixed with Water, inſomuch that there is no healthy Urine without a Portion of Oil in it intimately combined with the Water. But the Salt of Urine has a notable ſaponaceous and deterſive Quality, as is evident not only from its mechanical Uſes for ſcowering, but alſo from its diuretic Quality as a Medicine; for if Salt of Urine be diſſolved and drank in Water of a Morning faſting, after Exerciſe, it proves highly diuretic.

[3] The Sal Ammoniacum ſo called, remains immutable even after it has been ſublimed by itſelf, or diſtilled with Water above a hundred times; whereas our animal Salts, as that of the Urine, immediately turn into an alcaline Nature upon the firſt Attack with the Fire.

[4] About thirty Years ago, namely, in the Year 1696, I was ſurpriſed to find that the Salt of Urine, mixed with Spirits of Nitre, ſhould compoſe an Aqua regia capable of diſſolving Gold; and the very ſame Effect had Urine, even after it had ſtood expoſed for many Years to Putrefaction, or even after it had been tortured with a Fire ſo violent as to produce the Phoſphorus. But I afterwards found that it was the pure Sea Salt in the Urine which formed the Aqua regia, which Salt being continuaally taken in with our Aliments, paſſes through all the Veſſels and Organs of the Body without ever receiving any Alteration, as *Helmont* formerly well obſerved; from whence he recommends it againſt the Stone. But this Salt is not

to be found in the Urine of thoſe Animals who take in no Sea Salt, as Oxen, Sheep, *&c.*

[5] *Homberg* imagined he had demonſtrated an Acid, when by forming a Lixivium of the calcined Aſhes obtained from ſeveral hundred Weight of Blood, he from thence obtained a very ſmall Quantity of Salt, which being mixed with three times as much Earth, and diſtilled with a moſt intenſe Fire, yielded an acid Spirit into the Receiver. But this was certainly obtained from the Sea Salt, ſince the Spirit would make Aqua regia like that of common Salt. But neither is an Acid natural to the human Body, ſince it ariſes only from the Aliments, nor does it exiſt as an Acid while circulating with our Humours; but it is only produced by the Force of Fire from its natural State, which is not acid.

[6] In this Univerſity it was formerly taught, that the human Salts were of an alcaline Nature; but it is now thirty Years ago (namely, in 1696) ſince I demonſtrated, that our Salts were neither alcaline, nor made any Effervescence with acid Liquors. It is indeed true, that Fire and Putrefaction form a Salt truly lixivial, as well from the Parts of Vegetables as Animals; but then ſuch a Salt is the Product of the Fire, and did not before exiſt as ſuch. Nor is there any volatile Salt naturally reſiding in the human Body, that is, no Salt which will aſcend with a degree of Heat no greater than that of boiling Water.

[7] By muriatic Salt we underſtand the common Rock or Sea Salt diſſolved in Water; and of this kind there is a ſmall Quantity in the Urine, but no more than what is adventitious, or taken in with the Aliments.

§. 378.

§. 378. The *Oil*[1] of the Urine, produced from the Fat attenuated by Attrition, appears to be ſimple, and of a peculiar Kind, differing from all other Oils; notwithſtanding it may ſeem at firſt to be of a different Nature from the different Proportions of Salt and Earth with which it is mixed; and it is from this Oil only that the Urine derives its Colour, and not from the Bile.

[1] The Oil is that Part which gives Colour to the Urine; but this is no more than the animal Fat diſſolved and attenuated by Attrition. Every Animal, even though fed barely by Water and Graſs, will from thence derive Milk, whoſe Cream may be formed into a congealed Oil, which we call Butter: ſo that no Animal is deſtitute of Fat, Part of which being more fluid than the reſt, circulates with the Blood, while the other Parts are depoſited in the Cells of the adipoſe Membrane. Now that Part of the Fat which circulates with the Blood does, by the continual Heat and Attrition, paſs through various Degrees of Attenuation, by which its Appearance is alter'd into a yellow, red, or flame Colour, as we ſee it appears when diſcharged in the Urine. Even the citron Colour of healthy Blood ariſes, in a great meaſure, from a determinate Quantity of Oil. When the Urine appears red, it is a Sign that the Heat of the Body is increaſed beyond its healthy Degree, by which the Oil is more highly attenuated and intimately mixed with the Urine than it naturally ought to be. But that the Colour of the Urine ariſes from the Oil is demonſtrable, inaſmuch as that which was diſcharged in the Morning appears concocted;

whereas after drinking, the Urine becomes gradually more pale, and depoſits the Taſte which it had in proportion to the Quantity of Water drank. But now this moſt pale Urine will recover both the Smell and Taſte of its Oil barely by ſtanding a few Hours, by which time the Oil may become ſo attenuated as to mix intimately with the Water, which is abſolutely neceſſary in order for it to tinge the Urine. And this Oil is ſome of the thinneſt in the whole Body. But ſometimes the fat Oil, which is depoſited in the Cells of the adipoſe Membrane returns again into the Blood, and by a more violent Attrition in the Veſſels, it tinges the Urine with that flame Colour and fœtid Smell which we obſerve in Fevers, which ſometimes ſo emaciate or waſte the Fat of the Body, that *Ruyſch* obſerves in an Epiſtle to me, that a Patient weighed thirty Pounds lighter; and *Liſter* extends his Obſervation even to eighty Pounds.

§. 379. The *Earth* [1] of the Urine appears ſo highly attenuated and intricately mixed with the reſt of the Principles, as to be quite concealed in them; but it lies hid frequently inviſible, in a volatile and ſubtle State both in the Water, Spirits, Salt and Oil; and when ſeparated from them, it appears ſimple or uncompounded, *white* [2], fixed, inſoluble in Water, inſipid, and inodorous.

[1] It is uſually one of the Characteriſtics in the Definition of Earth, that it is not diſſolvable in Water: but this is true only of thoſe groſſer Particles of the Earth which are conſpicuous to the Eye; for it may be ſo attenuated as to become colourleſs and inviſible while it floats in a pellucid

Liquor, though it is nevertheleſs the ſame immutable Earth. The *Britiſh* Chalk and Tobacco-pipe Clay are to be enumerated among thoſe Bodies which are the leaſt alterable; for they only ſuſtain the Violence of the ſolar Fire in the Focus of the burning Lens of *Tſchirnhauſen*, when at the ſame time Gold and Silver are volatilized and exhaled. But this ſame Chalk may be ſo ſuſpended in a pellucid Liquor as to be inviſible to the Eye, namely, in diſtilled Vinegar: but if to the ſame ſaturated Vinegar you pour Oil of Tartar per deliquium, you will be ſurprized to ſee the Earth renew its Appearance, and ſubſide in little Fleeces to the Bottom of the Veſſel without having ſuffered any manner of Alteration in its Nature. A Perſon has no Reaſon to be afraid of ſpoiling the pellucid Colour of Water which the Earth ſeems to obſcure; for even the moſt cryſtalline Glaſs itſelf, which is the moſt pellucid of ſolid Bodies, is formed merely of Earth and Salt combined by the violent Action of the Fire.

[2] All pure Earth is white, and if ever Earth appears of ſome Colour, it is almoſt conſtantly tinged with Iron, which is a Metal abounding with Sulphur, and lies concealed almoſt in all Sorts of Clay. But this Earth of the Urine is an Aſſemblage of the ſolid Elements or conſtituent Particles of the ſolid Fibres in the human Body, ſeveral of which being connected together form one of the moſt ſimple Fibres; therefore each of theſe Particles are inviſible alone, but become conſpicuous when ſeveral of them are joined together into a Maſs by the Intervention of a glutinous Subſtance; but this connecting Glue reſides in all organic or living Bodies, more eſpecially in Plants, in which it ſo firmly connects thoſe ſolid Elements together, that they are not ſeparable but by the moſt intenſe Action

of Fire. Theſe elementary Particles of the Solids, many of which compoſe the ſolid Fibres, being continually abraded by the Impulſe of the circulating Humours, return into the Veins and Heart; from whence they are depoſited almoſt no where but in the Kidneys, through which this Earth is waſhed out with the Urine, a Liquor more repleniſhed with Earth than any other Humour in the Body: for we ſee this Earth depoſit itſelf from the Urine of the moſt healthy Perſon to the Sides and Bottom of the containing Veſſel; and even the Blood itſelf is not wholly deſtitute of earthy Particles, nor is there any ſolid or fluid Part of the Body which after Calcination does not afford a moſt pure and white Earth. But even this Earth itſelf is the Matter of Calculi, whoſe chief Reſidence is in the Kidneys, which alone free the Blood from the Minerals productive of this lamentable Diſorder. It is therefore ſufficiently evident, that a ſound State of the Kidneys is eſſentially neceſſary to produce a firm and healthy Condition of the Body.

§. 380. But we obſerve that neither the nutritious or well digeſted *Serum* [1], nor good Chyle itſelf, or *Milk* [2], are ever found in the Urine in a natural State. But how are theſe Juices prevented from eſcaping? Is it not from their Thickneſs in Conjunction with the Smallneſs and Convolutions of the uriniferous Veſſels?

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[1] A certain celebrated Profeſſer of Chemiſtry publickly taught, that the Serum of the Blood was to be found in the Urine; but in order to be ſatisfied of this Point, I examined above a hundred Pints of Urine, but never could ſee that it contained

ed any thing which would congeal like the white of an Egg by the boiling of Water. In the Year 1725 I collected a whole Caſk full of Urine, which I inſpiſſated till a hundred Pounds were reduced to one, for I was about to prepare the Phoſphorus, but yet I could never find any thing in the Urine which would cut like a boiled Egg. But the Reaſon why none of the hardening Humours paſs through the renal Ducts, ſeems to ariſe from their Smallneſs with the compact Texture of the Kidneys, preventing their too eaſy Dilatation, aſſiſted by the Mæanders or ſerpentine Courſe of the Arteries; each of which ſeems to be an Obſtacle preventing Liquors, which are ſo thick as the Serum of the Blood, from paſſing through the uriniferous Ducts.

[2] There was a certain Woman who dwelt at the City of *Dort*, who bore and ſuckled Children for twelve Years ſucceſſively; but at length ſhe fell into a lacteal Diabetes, in which all the Nouriſhment that was taken ran through her Breaſts without any Suction, under the Appearance of Milk; inſomuch that if ſhe drank a Pint of Ale, there was almoſt the like Quantity of Milk evacuated from her Breaſts: but after nine Months Affliction with this Diſorder ſhe was at length cured, but yet this Woman never depoſited any thing of Milk in her Urine. However, the renal Ducts are ſometimes ſo much relaxed by the Abuſe of warm watery Liquors, or otherwiſe, that they even tranſmit the Milk or Chyle itſelf, producing a lacteal Diabetes, which ſoon deſtroys the Patient with an Atrophy. But the Reaſon why the Milk does not naturally paſs this way, ſeems to depend much upon the Difference of the Orifices of the lacteal Veſſels from thoſe of the uriniferous Ducts: we ſee that the Breaſts are ſo alterable, that in Nurſes they are

ſurpriſingly diſtended; but after they have been exhauſted of the Milk by the Infant, they are reduced to a very ſmall Compaſs; whereas the Conſtancy and Firmneſs of theſe Veſſels in the Kidney is ſuch as admits not of the like Variation.

§. 381. Therefore in a healthy State there is never any Humour voided through the Kidneys which is *thicker* [1], or ſo thick as the Blood, its Serum, Chyle, or Milk: and hence *Waters* [2], eſpecially the *ſaline* [3], drank cold are diuretic; but fermented Liquors are the leaſt diuretic, (§. 56.) and the leſs as they abound more with *oily* [4] Particles. But acid and thin Wines very ſoon paſs off by Urine.

[1] We cannot but reflect with ſome Remorſe upon the many Obſervations which have been made in the Practice of Phyſick, when we find moſt of them ſo inaccurate, that we can ſcarce confide in them, or build any thing with Reaſon upon them. I have frequently endeavoured to diſcover whether any of the Milk, Chyle, or Serum of the Blood itſelf was evacuated in the Urine in a healthy State. There are indeed ſome Inſtances of polypous or grumous Blood having been diſcharged by the urinary Paſſages, of which Diſorder periſhed one of the Profeſſors of this Univerſity of *Leyden*; but theſe Grumes were derived from the Bladder, and not ſecreted in the Kidney. I alſo find ſmall Calculi larger than the Blood-globules floating in the Urine, but theſe are generally formed in the membranous Productions of the Kidneys, namely, in the Pelvis, Ureter and Bladder; for they were not ſo large at the time of paſſing through the cortical Subſtance of the Kidney itſelf. There are ſome

Authors who tell us of a Grain of Barley being ſwallowed, and afterwards evacuated by Urine: but in ſuch a Caſe there muſt have been a preternatural Perforation or Dilatation of the Veſſels, which collapſed again after the foreign Body had paſſed through. Thus I ſaw a leaden Bullet which by degrees made its way towards the Skin, appearing firſt under the Cuticle to the Touch, and afterwards making its own way through the Skin itſelf with ſo little Injury to it, that there ſeemed to be almoſt no Opening left behind: and in the ſome Manner Fragments of Bones make their way towards the Skin and are diſcharged out of the Body. But all theſe are extraordinary Inſtances, and not to be alledged as the Conſequences of the natural Fabric of the Parts. We are likewiſe furniſhed with many Obſervations of Matter evacuated with the Urine upon the drying up of an Ulcer; but that Matter is not diſcharged in the thick and tenacious Condition in which it uſually appears, but it is firſt highly attenuated, diluted, and again aſſembled together after the Urine has ſtood ſome time in the Pot, ſo as by the Viſcidity of its Parts to regain the Appearance of Pus or Matter. Theſe Experiments therefore by no means prove that Humours as thick as laudable Matter paſs through the renal Ducts; for if ſuch a kind of Reaſoning was to be admitted, one might eaſily demonſtrate, that a Cylinder of common Salt as thick as ones Finger paſſed through the renal Veſſels: for certain we are that ſuch a Cylinder may be diſſolved in Water, drank, diſcharged in the Urine, and again cryſtalized into its former Bulk; and therefore Lumps of Salt are as well evacuated through the Kidneys, as the purulent Matter obſerved by theſe practical Writers.

[2] Water is the beſt of all Diuretics, eſpecially when its Force is increaſed by drinking it cold, and mixed with Salts; for if the Water be warm, it rather inclines to ſweating.

[3] Salts that are alcaline both fixed and volatile, Sal Ammoniacum, the eſſential Salt, and Spirit of Urine, with cooling Salts, which do not incline to ſweating, ſuch as Nitre, Sea Salt, *&c.* To theſe add the recent Urine drank warm from a Cow, the Juice or Liquor of Oyſters, or Muſcles and Cockles diluted with Water, the Tartar of Wine, Vinegar and Water, which all cool and promote Urine. But Cantharides and Millepedes are not diuretic, but operate by inflaming the Bladder.

[4] Oily and ſweet Wines, and ſuch as the *Spaniſh*, with diſtilled inflammable Spirits, can neither be drank in large Quantities, nor readily diſcharged by Urine: but thin acid Wines are by Drinkers often ſwallowed to an immenſe Quantity, and they eaſily paſs off by Urine with little or no Detriment.

§. 382. From hence we are capable of reſolving the Queſtions, from whence ariſe the *Quantity* [1], *Colour* [2], *Smell* [3], *Taſte* [4], *Conſiſtence* [5], and *Contents* [6] of the Urine, with what floats upon the *Surface* [7], is ſuſpended *in* [8] the middle, or *ſubſides* [9] to the bottom of that Liquor? Namely, that theſe ariſe variouſly, according to the different Quantity of Water, Spirit, Oil, Salt and Earth entering into the Compoſition of the Urine, more or leſs intimately combined, according to the different Degree of Attrition which they have ſuffered in the Veſſels. And this is more eſpecially demonſtrated beyond other things by the *Phoſphorus* [10].

A large

[1] A large Quantity of Urine is voided, when watery Liquors have been drank plentifully, and the Kidneys likewiſe appear very compact.

[2] The Colour ariſes from the Fat combined with the Water by the Heat and Attrition of the circulating Blood; for pure Salt is always white: but Oil, though ever ſo white, does by Heat and Attrition become rancid and yellow. If Bacon or Lard be ſuſpended in a warm Air, its white Colour changes into a yellow, and at the ſame time acquires a rank Smell and Taſte. The Colour of the Urine increaſes from that of a pale Straw, and according to the Velocity or Heat of the Blood, it paſſes through all the various Degrees of Redneſs even to a black, and then Death is either at the Door, or has actually taken Poſſeſſion, as we are aſſured in the Plague, ardent Fevers, *&c.* But here it is to be obſerv'd, that the Intenſity of the Colour does not ariſe from the Quantity of the Oil, but from the Degree of Corruption: for the moſt healthy Urine will barely by ſtanding and putrefying become red, and even black, without at all increaſing the Quantity of its Oil.

[3] The Smell of the Urine ariſes from its Oil, as we obſerved before; for Salt being well cleanſed from its Oil is inodorous: and in Diſtillations the ſaline Part of the Urine remains at the bottom, while thoſe Parts which have the ſtrongeſt Smell aſcend together with the Water. But the fœtid Smell of the Urine is increaſed in ardent Fevers from the Intenſity of the Heat: for nothing putrefies ſooner than Oils, and ſtinking Smells ariſe only from the Oils turning alcaline. Therefore by ſeparating the Oil from the Urine, it will be deprived of its Smell.

[4] Its Taſte is very peculiar, nauſeous, ſulphureous, bitteriſh, ſubputrid, and in moſt acute Diſeaſes cadaverous.

[5] Its Thickneſs or Conſiſtence ariſes from the Oil, Salt, and Earth conjunctly; for Water is thinner than theſe, and Spirits, if there be any in the Urine, are ſtill thinner than Water. Therefore the Conſiſtence of the Urine is in proportion to the Quantity of Water inverſly, increaſing as the Quantity of Water is diſſipated or diminiſhed: and from the ſame Cauſe likewiſe the Smell, Colour and Saltneſs will be alſo increaſed or diminiſhed with the Thickneſs of the Urine. But the greateſt Conſiſtence of the Urine is derived from the Earth, or the ſolid Stamina, which have been abraded by the circulating Humours from the ſmalleſt Fibres and Veſſels of the Body: and of this nature is the lateritious Sediment, which ſubſides in the Urine after the Paroxyſm of an intermitting Fever; and the like Matter is alſo depoſited in the Scurvy, the moſt certain Sign of which may be deduced from this copious Sediment of the Urine. Hence therefore we may be capable of judging concerning the State and Condition of the Blood, from the Smell, Taſte, Colour, and Conſiſtence of the Urine, which if paler than ordinary, denotes a Diminution of the vital Powers; but if redder than uſual, denotes that the Vis Vitæ is too intenſe.

[6] The Contents of the Urine ariſe chiefly from the oily and earthy Particles combined; and to this Head belong the beneficial Sordes, which render the Urine of febrile Patients turbid. Even if you view it with a Microſcope, you will ſee pyramidal Corpuſcles, which are the true Matter of calculous Concretions.

[7] What floats upon the Surface of the Urine in the Form of Clouds or Skins, ariſe from the Oil and moſt ſubtilized Earth ſo much attenuated as to be capable of ſwimming in Water. Their Dif-

ference reſults from the Proportion of the Oil to the Earth; and from their more or leſs Lightneſs and intimate Mixture. The Nubeculæ or Clouds proceed chiefly from the muriatic Salt. The *Dutch* Sailors after returning from *Aſia*, when they have lived for ſeveral Months only upon ſalted Proviſions, and drank but little Water, they void a cloudy Urine, which Clouds being viewed with a Microſcope appear to be Sea Salt.

[8] The ſuſpended Matters in the Urine are indeed mixed with Water, but are rather heavier of the two; and they differ from the former in containing more Earth, which is the Cauſe of their being heavier.

[9] The Hypoſtaſis or Sediment of the Urine reſults from the ſalt Earth and ſandy Particles. But to theſe we ought to add thoſe Contents of the Urine, which adhere to the Sides in the Form of Cryſtals or Tartar.

[10] Phoſphorus is a ſurpriſing Body, diſcover'd or invented by a *German* Chemiſt, named *Kroft*, and afterwards deſcribed by *Kunkel*, and is made in the following manner. Take a large Quantity of human Urine, as containing more Phoſphorus than Blood, and expoſe it for a long time to Putrefaction; after which diſtil it to Drineſs in ſtrong and cloſe Veſſels, till all the fluid Parts are drawn off, and what remains behind appears black and dry like a burned Coal. In the next place, let the Receiver be changed, and another adapted which is full of Water, and let the Fire be increaſed throughout all the Degrees, till after a few Hours, and not before, the Phoſphorus will begin to ariſe with a Fire, which is ſufficient to make the Iron Retort glowing or white with Heat: thus will a bluiſh-colour'd Fume ariſe and paſs into the Receiver almoſt like the Flame of burning Sulphur,

which will ſink to the bottom of the Water, and run together in Flakes of a pale Blue, ſhining in the Dark, and in the open Air burſting into Flames; but which may be preſerved many Years without burning, provided it is kept under Water, and well ſecured from all Commerce with the Air. This is certainly a wonderful Inſtance of the Power exerted by Fire in changing Bodies. We have here a ſurpriſing Subſtance, which is neither Salt, Earth, Oil nor Spirit, but a new Subſtance or kind of Body very little known to us. It is not Oil, notwithſtanding it diſſolves in Oil; ſince upon mixing it with boiling Water, it does not afford any Marks of Fatneſs; but as it diſſolves in Oil and Alcohol, burns and ſmells without mixing with Water, it may therefore be not improperly referred to the Claſs of oily or ſulphureous Bodies.

§. 383. Alſo the Reaſon will be from hence evident, why *bloody Urine* [1] is often obſerved after violent Motion, or other Exerciſes, notwithſtanding the Kidneys are ſound, and there is no room to ſuſpect a Calculus.

[1] It is an Experiment of *Peyerus*, that if you inject Water heated to the hundredth Degree of the Thermometer into the renal Artery, and continue it for ſome time, the Kidney will then become extemely white; and if then you inject ſome coloured Liquor, it will paſs together with the tinging Ingredients into the Pelvis and Ureter. It frequently happens, that healthy People of a weak Habit are ſurpriſed to find themſelves of a ſudden diſcharge bloody Urine, after they have been carry'd ſwiftly over the Stones in a Cart or

Waggon to which they have not been accuſtom'd. I for a long time did not underſtand the Reaſon of this Phænomenon, which I had often obſerved: but at length I perceived the whole Affair in a learned Man, who underſtood the Make of his own Body. For after riding an uneaſy Horſe with great Expedition upon urgent Buſineſs, he found that upon his Return he made bloody Urine. Being thus affrighted, he made no doubt but that the Blood came from a Rupture of the Blood-veſſels in the Kidneys, and was therefore perſuading himſelf that he muſt have a very bad Stone: hereupon he conſults a Phyſician, who from the ſame Theory orders Oil of Almonds, to abate the inflammatory Heat of the Kidneys, and mitigate the Aſperities of the ſuppoſed Calculus. But the Patient ſoon after voids Urine with a Sediment very much like purulent Matter; whence he becomes more ſtrongly confirmed in his Opinion of a Stone, when in reality the ſuppoſed Matter was pure Oil of Almonds. The Patient therefore making no doubt of a Calculus, calls another Phyſician (myſelf) who conſidering the Hiſtory of the Diſeaſe, and finding no Signs of a Calculus, plainly perceived that florid Blood without any Grumes had been forced through the Kidneys by the violent Exerciſe; and what he afterwards ſuppoſed, and called the Mucus of the Bladder, was no more than the Oil of Almonds; I therefore concluded from a Conſideration of the Circumſtances, that the Blood being put into a violent Motion by the Exerciſe, had dilated the uriniferous Ducts of the Kidneys, and paſſed through the Tubuli of *Bellini*, and that after this the Oil of Almonds had paſſed the ſame way; and therefore the Patient was cured in a few Days time merely by Reſt and a thin Diet. This Way of diſcharging Blood in the Urine often happens in acute Diſeaſes, barely from the Continuity or opening of the renal Arteries into the uriniferous Ducts, as happens in moſt acute and peſtilentious Fevers, the Small-Pox, Pleureſies, *&c.* in which it proves very fatal, inſomuch that *Sydenham* mentions only one who recovered after this Symptom in the Small-Pox during his Obſervation.

§. 384. From what has been ſaid alſo (§. 318 to 383,) an Anſwer may be given, whether a Separation of the Urine through the Kidneys is abſolutely neceſſary for the Preſervation of Health? or whether it may not be ſupplied by ſubſtituting other *Excretions*[1]? and laſtly, of what *Uſe*[2] it is to the Body.

[1] I am perſuaded from many Obſervations that an intire Suppreſſion of Urine muſt be mortal, and that the Patient cannot ſurvive it above fifteen Days for the moſt part. *Drelincourt* having tied the Ureters in living Dogs and replaced the Inteſtines, turned the Animals looſe and ſupplied them with Food, but yet they did not ſurvive it. I have tried ſeveral Methods in the moſt deſperate Caſes, and amongſt others repeated Bleeding, which yet ſcarce retarded the Patient's Death for more than a few Days, at which we need not wonder: for if among ſixty Pounds of Blood there are ſix of Urine, the taking away of ten Pounds of Blood will ſtill leave Urine enough behind to deſtroy the Patient. I have ſometimes excited a Vomit twice a Day, and uſed Purges of Jalap, but without any Relief to the Patient. Acids indeed relieved them more, but neither could any of theſe ſave them: for ſome Days after the Begin-

ning of the Diſorder, they begin to imagine themſelves over Head and Ears in the Water, which is a Sign that the Brain begins to be overflowed with Serum; and after this the Breath and Sweat ſmell of Urine, all the Senſes are ſtupified, and the Diſorder ſeems to be leſs troubleſome, except perhaps the Terror which the Patient conceives from the Apprehenſion of his approaching Death, and at laſt the incurable Diſorder paſſing through all the Degrees of Stupidity and Sleepineſs, terminates in an Apoplexy and Death itſelf; and upon opening the Body, hardly any other Cauſe of Death can be found than a quantity of fœtid Water filling the Ventricles of the Brain, that is, ſome of the extravaſed Urine. There was a certain Miniſter at the *Hague* charged with very important Negotiations, who through the Multiplicity of his Affairs neglected to make Water for a whole Day and Night, and upon endeavouring the next Day at Noon to diſcharge the Urine which he had ſo long retained, nothing could be evacuated. Upon the third Day a Catheter was introduced into the Bladder, but no Urine was evacuated; and on the fourteenth or fifteenth Day he expired. The Symptoms that attended were a Drowſineſs on the ſixth Day, followed with a Sleepineſs, and dreams of being drowned, Breath and Sweat ſtinking, the Pulſe increaſed, Convulſions, a Lethargy, and at laſt Death itſelf; and in the Ventricles of the Brain was found a Quantity of Urine.

[2] The Uſe of this Secretion is, 1. To free the Blood from its acrid and offenſive Oil. 2. To cleanſe the Blood from its ſtony or mineral Particles, which form Calculi in different Parts of the Body, if they are not waſhed out with the Urine. And beſides that, to ſeparate the Oil, which is become injurious by too great Attrition and Rancidity,

cidity, by which its Salts are too much inclined to be alcaline. But yet the Cauſe of the Patient's Death after a Suppreſſion of the Urine, is not from an alcaline Diſpoſition of the Blood or Urine; for if it was ſo, they might be preſerved by a plentiful Uſe of Acids, which is contrary to Experience. I extracted a moſt fœtid and acrid Urine from a Profeſſor of this Univerſity, who died of an Iſchuria; and to that Urine I poured Acids, but no Struggle or Effervеſcence followed. And therefore it is evident, that an alcaline Diſpoſition does not ariſe in our Humours, but what their Acrimony will firſt conſiderably injure the Brain, and put a Period to Life.

But another Uſe of the Kidneys is to prevent the Formation of Calculi in the ſeveral Parts of the human Body: for the ſolid and earthy Stamina broke off from the Fibres are diſcharged with the Urine, ſo as to adhere to and obſcure the pureſt Veſſel, forming at length a Cruſt, and by degrees a Calculus, the Principles of which I have demonſtrated to be the ſame with Bones, Horns, Nails, *&c.*

§. 385. Since therefore the *Motion* [1] of the Humours, the Structure of the Body, with *Ligatures* [2], *Injections* [3], and occular Inſpection, joined with the *Diſtempers* [4] ariſing from a Suppreſſion of the Urine, do very plainly teach us, that this Excrement can be only diſcharged conveniently by theſe ways from the Blood: there is therefore no Occaſion to ſuppoſe or imagine Paſſages from the *Stomach* [5] and inteſtines diſcharging Liquors from their Cavities into that of the Peritonæum; and then again to ſuppoſe correſponding Pores ſeated, as well in the Membrane which is extended over the Pelvis and Bladder, as alſo in the Bladder itſelf, by which Pores the Urine may be abſorded and conveyed directly into the Cavity of the Bladder; as alſo that there is no Obſtacle to reſiſt ſuch a Courſe of the Urine, but that the Courſe is quite free and expeditious. Laſtly, To ſuppoſe or invent the Appearances which ſuch a Paſſage requires, when at the ſame time there are no Arguments which can be brought to prove the Paſſage itſelf.

[1] The Urine flows laſt from the Urethra, which receives it from the Bladder, the Bladder from the Ureters, the Ureters from the Pelves, and the Pelves from the Papillæ; which Papillæ receive the Urine from the Tubuli of *Bellini*, and theſe laſt receive it from the ſmall Arteries themſelves, which are continued from the renal Arteries. So that from the firſt to the laſt, the Urine paſſes from the renal Arteries into the Urethra.

[2] This Experiment has been frequently made by *Drelincourt*. He opened the Abdomen of a living Dog, taking care to prevent too great Injury from being offered to the Blood-veſſels; and he then made a Ligature upon the Arteries: hereupon the Dog evacuated what Urine remained in his Bladder almoſt ſo entirely, that ſcarce a Drop remained, and ſome time after the Animal died lethargic; but upon opening the Bladder, it was found perfectly empty.

[3] Urine being mixed with Ink, and injected by the emulgent Artery, runs partly into the cor-

reſponding Vein, and Part of it penetrates into the uriniferous Ducts, Ureters, and Bladder.

[4] Certain Death follows, when a Perſon has both Kidneys or both Ureters obſtructed by a Calculus, or by any other Cauſe; and upon opening the Bodies of ſuch Perſons after Death, the Bladder is found empty.

[5] There have been at all Times, and in all Ages, certain Perſons who have ſought after a different Paſſage of the Urine from that which it takes through the Kidneys, which was believed too ſhort a Courſe. There are Fibres deſcribed as paſſing from the Stomach to the Bladder, in *Hippocrates*'s Book *De locis in homine*, which we may perhaps interpret to be the Ureters, for any other Courſe appears to have been refuted by *Eraſiſtratus:* but the Opinion was revived again ſome Years ago, and is at length almoſt expunged. About the Beginning of the preſent Century, it was propoſed in the Memoirs of the Royal Academy of Sciences at *Paris*, that there were two kinds of Urine; one which is commonly ſo called, containing the oily, ſaline, and earthy Parts of the Blood which are ſeparated in the Kidneys; and another ſort of Urine which is very thin and watery, paſſing through new Pores or Ducts into the Bladder. This Opinion was propoſed by its Author with ſo many ſeeming Advantages on its Side, that he hoped it would be univerſally allowed without Difficulty by all. It was therefore the Opinion of the learned Members of that Academy, that the Urine properly ſo called, had a different Paſſage from that which is commonly known into the Bladder, by whoſe Pores it was abſorded without firſt paſſing through the Kidneys. After reading the ample Demonſtration of *Morinus* in the Memoirs of the Academy for 1701, I could not

conceive any Conviction in it. His Reaſoning ſeemed to be to the following Purpoſe: That all the Drink paſſes into the Stomach, but that a conſiderable Part of it was abſorded through the Pores of the Stomach; and ſo far his Poſition is true enough. But it is then added, that the abſorbed Liquor paſſes through the Pores of the Stomach into the Cavity of the Abdomen; whereas this is a falſe Propoſition: for the abſorbing Pores in the Stomach belong to the Veins; but the Veins do not exhale nor diſcharge any Liquor either out of the Body, nor into the Cavity of the Abdomen, but return their abſorbed Liquors into the larger Veins, thence paſſing by them to the Heart, and from the Heart to the Arteries. It is then added, that the abſorbed Liquor diſtilling like Dew through the Pores of the Stomach, is applied to the Surface of the Peritonæum, which lies next to the Bladder; and being again abſorbed through the Pores of that Membrane, paſſes to the Bladder itſelf, by whoſe Pores alſo it is abſorbed, and falls into its Cavity; and thus there is an immediate and ready Paſſage given to Liquors from the Stomach into the Bladder, without paſſing either into the Blood, or going through the Heart, Lungs, Arteries, and Kidneys. But no Perſon cou'd ever demonſtrate, that the Water which is transfuſed into the Cavity of the Abdomen, is ever abſorbed through the Pores of the Bladder, notwithſtanding they make it one of their Arguments, that dropſical Patients have thus a ready Paſſage for evacuating the Water by diuretic Medicines. For when that Water is diſcharged by Urine, it returns through the Veins into the Blood. But if there was another Courſe for the Urine to paſs into the Bladder, diſtinct from that of the Kidneys; what Reaſon can be given, why thoſe Patients are killed,

led, who have a total Obſtruction of both Kidneys, or both Ureters, either by an Inflammation or a Calculus. For in a Suppreſſion of Urine ariſing from theſe Cauſes, not a ſingle Drop of Urine paſſes into the Bladder, nor out of the Body, except a few Drops of Mucus which ariſe from a different Quarter; and what is ſtill more, the Bladder is uſually found empty after the Death of ſuch a Patient, which is ſeldom protracted beyond the fifteenth Day. But if the Bladder has abſorbing Pores by which Urine can paſs into it, as well as by the Ureters, why do we not find the Bladder filled in theſe Diſeaſes by abſorbing the Urine? But they proceed to confirm their Reaſonings by Experiments; for, ſay they, if the Stomach be either inverted or not, and the Pilorus is accurately tied, while its Capacity is filled with Water by the other Orifice; if the Stomach be then ſuſpended, it will in a few Hours quite empty itſelf; and therefore they think it evident to a Demonſtration, that there is a Paſſage in a dead Body from the Cavity of the Stomach through all its Membranes, by which Liquors may freely paſs into the Cavity of the Abdomen. But this is a very great Fallacy, for when the Stomach is taken out of the Body, it is cut off from its Connection with all the other Viſcera, from the Pancreas, Colon, Omentum, *&c.* In doing which the Veins are divided, namely, the Epiploic, Pyloric, Vaſa brevia, *&c.* by which the Stomach communicates with thoſe Parts. Therefore the Water which is abſorbed by the bibulous Ducts of the Stomach, paſſes into the Trunks of theſe divided Veins, and flows out through them: but if thoſe Veins were not divided, it would paſs into the Maſs of Blood. The laſt Experiment urged in favour of this new Courſe, is, that warm Water or mineral Waters are evacuated almoſt as ſoon as they are drank. But even this Obſervation has no Force in favour of their Hypotheſis. For it is not that Water which is immediately drank, which paſſes into the Bladder, and urges the Patient to Urine; but it is from the other old Water and Humours of the Blood being propelled and forced more ſwiftly through the Kidneys by the cold Water laſt drank, by which alſo the Bladder itſelf is urged to evacuate its Contents. Hence it is that never ſo much Urine is evacuated, as there is Water drank, but always ſomething leſs. If after drinking the firſt Draught, another Draught be again taken after a ſhort Interval, the former will be expelled by the latter; ſo that the firſt Draught will be expelled by the third, the ſecond by the fourth, and ſo on in ſuch a manner, that what is laſt drank will never be expelled until there is an Acceſſion of more. That this is the Courſe or Manner in which mineral Waters are voided is demonſtrable, 1. Becauſe the Urine which is diſcharged after drinking the firſt Draught in the Morning, whether hot or cold, appears by its Colour and Smell to be the concocted Urine of the Blood and Chyle, and not the Remains of the mineral Water. 2. Becauſe the Urine which is voided after the ſecond Draught, appears half concocted, paler than the former, but yet tinged with ſome Colour, and therefore neither is the Urine of the mineral Water voided at the ſecond time. 3. The Urine which is voided in the next or third place, is the firſt that appears pale or watry, and by its Colour or Smell ſeems to be the Remains of the Water which was firſt drank. 4. All the Water which is drank is never entirely voided in an equal Quantity by Urine; but if ten Pints were drank, about eight of them will be thus evacuated; which is a manifeſt

Indication, that the Pint laſt drank is not immediately diſcharged, but is retained for ſome time in the Blood-veſſels, which it in part fills; and there waits, till by a ſucceeding Draught it is in a manner urged, as it were, by Preſſure in a continued Stream through a Tube.

§. 386. From hence alſo we may perhaps be able to determine, whether the Kidneys conduce any thing to the Formation of the *Semen*[1], and how far they conduce towards it? at leaſt the Vicinity of the emulgent and ſpermatic Arteries, denotes ſome latent Sympathy betwixt theſe Parts.

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[1] It is a common Phraſe among the ancient *Hebrews* with the Inhabitants of *Aſia*, *Arabia*, and *Syria*, to ſpeak of their Children and Kindred, as having deſcended in common from the Loins of their Grandfather: in favour of which Diction, we may alledge the conſtant Vicinity that is found betwixt the ſpermatic and emulgent Arteries, not only in Man but alſo in brute Animals; and the ſpermatic Vein on the left Side almoſt continually diſcharges itſelf into the emulgent Vein of the ſame Side. The ſeminal Veſicles in all Animals are conſtantly fixed at the Neck of the Bladder, but yet this is no Foundation for the Reaſon alledged by *Galen*, namely, that the ſubputrid and ſaline Urine might mix with the Seed to produce the greater Titilation: for there is nothing putrid in the Semen, even though it has been retained for many Years in its Veſicles, but is always of a mild balſamic Nature. But I am afraid we can have but little Hopes of expecting any Light into this Affair, from the Diſcoveries of *Valſalva*.

Swammerdam, *Redi*, and other Naturaliſts demonſtrate, that all Fowls and Birds, and alſo Fiſh do evacuate Urine, though in a different Manner from Quadrupeds.

§. 387. Laſtly, it may alſo appear from what has been ſaid, why *Gravel*[1] and *Stones*[2] are ſo frequently formed from the Urine, in its ſeveral Paſſages?

[1] It is demonſtrated in another Place (§. 434.) that the human Body continues the ſame but for a very ſhort time, its ſeveral Parts being continually changed, till at length the whole is renovated. The Nails or Hair being cut or ſhaved off at the uſual times, are ſupplied with more of the ſame Kind; and even if a large Part of a broken Bone be taken out, ſo as to leave a conſiderable Space, the whole Cavity will be filled up in a few Months with a Subſtance nearly reſembling that of the Bone itſelf, ſo that in three Months the Bone will be reſtored to its former Continuity. In *Aſia* it has been cuſtomary for People through all Ages paſt, to let their Beards grow; and the *Europeans* who live there being accuſtomed before to ſhave their Beards very cloſe, are nevertheleſs furniſhed in about ſix Months time with a Beard as long as the reſt; nor will it grow to any greater Length, even though it be continued for a longer time; and therefore thoſe who have continued their Beards for many Years, have them by degrees changed by the Production of new Hairs. We ſee that all the hard and ſoft Parts of a Chicken are produced in the Space of twenty-four Days, from the fluctuating white of an Egg: and even Man himſelf ariſes from an inſenſible Drop of the ſeminal Fluid. From all this it is evident, that all

the ſolid Parts of the Body which have performed their proper Offices, are continually abraded and conſumed, while at the ſame time there is a perpetual Renovation or Reſtitution made of new Matter to ſupply the Place of the old; and this properly is the Nutrition of an adult Perſon, namely, for the ſolid Parts to be ſupplied with as much Matter from the Humours, as is daily waſted and caſt off from the Body: ſo that every ſolid Part of the human Body which has performed its Office, is continually evacuated or caſt off; but whether or no theſe Exuviæ become firſt acrid, I cannot determine. But theſe ſolid Staminæ or earthy Particles of the Body can neither be diſcharged by the Inteſtines, nor by the Skin in the Form of perſpirable Vapours or Sweat, and therefore it follows, that they muſt be depoſited in the Kidneys, and evacuated together with the Urine; ſo that a Retention of them in the Kidneys will produce a Stone. But that the Kidneys only are the proper Outlets for theſe excrementitious ſolid Particles, may be eaſily demonſtrated by Experiment. For if you take Urine as it flows warm from the Body into capillary Glaſs Tubes, and view it with a Microſcope in the Rays of the Sun, it will at firſt appear pellucid, till at length it will continually depoſit little Scales, which are the true conſtituent Particles of a Calculus, and will in a little time fix themſelves to the Sides of the Glaſs Tube. Thus we alſo ſee a ſtony Cruſt of the ſame Nature formed about the Sides and Bottoms of Chamber-pots; which Cruſt is at firſt very thin, but increaſes by new Strata, which if not ſcoured off, while more Urine is continually poured into the ſame Veſſel, it increaſes ſometimes to ſuch a degree, as totally to cover the internal Surface of the Glaſs or Receptacle in which it ſtood.

If theſe Particles are not continually waſhed out of the Body, but fix themſelves in any Part, they form a Magnet, to which the ſimilar ſtony Particles will adhere, and from hence will ariſe a Calculus. Even in any Part of the Body, not excepting the Brain and Teſticles, a Calculus will be formed if there is but the leaſt ſolid Particle to which that ſabulous Matter may adhere, which ought to be depoſited in the Urine: but a human Calculus appears to be a hard friable Body, diſſolvable in no Liquor as hitherto diſcovered, except Spirit of Nitre. We know by Experience that a Magnet or Baſis may be formed for the Adheſion of theſe ſabulous Particles of a ſmall Grume of Blood, Matter, a Bit of Wool, a little Membrane, a Splinter of Wood, a Fragment of Glaſs, or Lead, or a Particle of any other kind of a ſolid Body. A leaden Bullet which was ſhot from a Gun into the Bladder, continued there for a conſiderable time without giving the Patient any great Uneaſineſs, nor did he complain of the Strangury for a long time afterwards; but after the Perſon's Deceaſe, a large Stone was found in the Bladder formed round the leaden Bullet. *Nucke* opened the Bladder of a living Dog, and inſerted a little Ball of Wood; the Animal was afterwards cured of his Wound: but when the Anatomiſt cut open his Abdomen ſome Months afterwards, he found a Stone formed round the wooden Spherule. A Tent ſlipping into the Bladder out of the Urethra by ſome Accident has been obſerved to lay the Baſis of a large Stone. If a Perſon does not uſe Exerciſe, while at the ſame time the uriniferous Ducts are compreſſed with too great a Load of Fat, the Paſſage of the Urine to the Bladder will be impeded, and the mealy Duſt or ſcabulous Particles of the Stone will continually ſtop in the Tubuli

Belliniani, whence a Calculus will be formed. The chief Preſervative therefore againſt the Stone, will conſiſt in keeping the urinary Paſſages continually clear, and free from any ſolid Particles to which the Matter of a Calculus may adhere: in order to which two things are to be avoided, namely, 1. Never to lie for a conſiderable time quite flat upon the Back. 2. Never to retain the Urine too long. But in the Beginning of the Diſorder, while the Gravel is ſmall and moveable, the beſt Method of relieving the Patient will be, by ordering him to drink a quarter of a Pint of warm Water before Meals, and to uſe moderate Exerciſe for about the Space of an Hour. Upon this Subject *Fernelius*, (*Pathol.* lib. vi. cap. 12.) deſerves to be conſulted, who is the firſt Phyſician that has wrote with Truth concerning the Calculus.

[2] The human Calculus is neither Salt nor Spirit, as *Helmont* imagined, nor is it Oil; but it is moſtly fixed or permanent Air combined with the earthy Particles, which have been rubbed off from the ſmalleſt Veſſels by the Force of the circulating Humours, intermixed and cemented together by ſome of the urinous Salts and Oils, ſo as to form a compact or ſolid Body.

Concerning the Structure and Action of the Muſcles.

§. 388. AFTER having ſurveyed what Actions are performed by the Blood in its Paſſage through the Viſcera, it will be neceſſary for us in the next place to examine what it performs in paſſing through all the *Muſcles* [1] of the Body, and then to enquire inro the *Action* [2] of the Blood, which is moved through the internal or external Integuments which inveſt either the Surface or internal Cavities of the Body.

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[1] A Muſcle is by the *Greeks* ſaid to be a Portion of Fleſh reſembling a Mouſe, that is, having a peaked Head, almoſt without any perceptible Neck, joined to a pretty long and round Body, and terminating in a long ſlender and round Tail or Tendon. By a Muſcle we mean an organical Part of the Body, capable of exciting, determining, or directing, and continuing the ſeveral Motions of all the Parts, at the Pleaſure of the Mind. And this Definition explains not the Nature but the proper and characteriſtic Action of a Muſcle. I am by no means pleaſed with the Definition which Philoſophers give of Things, by intermixing their Natures or Deſcriptions; as for inſtance, in defining Gold, to give us an Aſſemblage of all the Ideas compoſing that Metal. If Philoſophers demand ſuch Definitons from Anatomiſts, it is more than we are capable of. But in my Judgment, a Body is rightly defined by aſſigning any one of its Characters, which are to be found in that and in no other Body: thus, for Example, Glaſs is a pellucid Body, brittle in the Cold, and formed of flint Stones or flinty Sand, combined with an alcaline Salt by the Force of Fire. This Character of Glaſs though it does not expound its Nature, is certainly ſufficient to diſtinguiſh it or prevent it from being confounded with all other Bodies. In the ſame manner we define a Muſcle; for there is no Part muſcular but what

is productive of animal Motion; and if you except againſt the Definition, that there are ſome Muſcles whoſe Actions are not governed by the Influence of the Will; I anſwer, that they are nevertheleſs of the ſame Fabric with thoſe Muſcles which are the Servants to execute the Inclinations of the Mind.

[2] We are in this Place therefore to examine in what manner the Muſcles follow the Influence of the Will: namely, as if a Perſon is walking with a quiet Mind, and thinks that after a hundred Steps he will have his right Hand held by his left, in a prone Situation; it is manifeſt that ſuch a Motion will proceed entirely from the Will. In order to explain this Motion, it cannot be ſuppoſed neceſſary to aſſign the Manner of its firſt determinating Cauſe; for this is not only out of human Capacity, but would be equally uſeleſs as it is impoſſible. If I am about to explain the Motion of a certain Ball marked A, and demonſtrate that it is moved by another Ball marked B, I ſhall have then performed the Taſk without enquiring from whence the Ball B derived its Motion. Again, for Inſtance: I ſee a Perſon in Health campoſe himſelf to Reſt in his Bed, and when he awakes in the Morning, he endeavours to draw the Curtain: ſuch a Perſon is then ſurpriſed to find that his Hand does not obey the Motion, which he inclined to perform; and it is the Cauſe of this Motion which the Hand poſſeſſed the Day before, but of which it is now deſtitute, that we ſhall take upon us to explain.

§. 389. But this being one of the moſt difficult and obſcure Subjects, as being ſeated in the *moſt minute* [1] Veſſels and *Inſtruments* [2] of the Body, it has occaſioned a great Variety of Opinions, and has at the ſame time render'd it difficult to chuſe the beſt.

[1] The ſmalleſt ſanguiferous Veſſels are ſcarce viſible by the Microſcope; but the Veſſels of which we here ſpeak may be ſome Myriads of times leſs than theſe: but notwithſtanding the Aſpect of ſo great a Difficulty, the human Mind, being impatient of Ignorance, has contrived various Methods by which this Motion may be brought about, inſomuch as to render it difficult to judge betwixt the contrary Doctrines of the Learned. But in general we are to obſerve this, that if a hundred are of different Opinions, there may be ſome Truth in each of them, as well as ſome Falacy, nor was any Propoſition ever ſtarted ſo perfect as to be without Defect. But if we collect together out of each Syſtem every thing which appears to be true, and join them into one, we ſhall then have an Edifice moderately perfect.

[2] In other Parts of the Body, the Microſcope and Injections aſſiſt us in determining their Structure; but in this Caſe both theſe Artifices are but of little Service to us. But it is firſt neceſſary to obtain a Knowledge of the Figure of any Inſtrument, in order to explain its Uſe, otherwiſe we muſt always deſpair of being ſatisfied that our Explanation is true. If you ſay an Inſtrument is Iron or Steel, you ſay nothing towards explaining its Uſe; but if you ſay an edged Inſtrument of Steel is ground into a Razor, you may be then capable of applying it to mechanical Principles, ſo as to explain the Power and Action of the known Inſtrument. Antiquity, it muſt be confeſſed, has left us no Aſſiſtance in this Affair; for all our Knowledge in this reſpect is owing to the Moderns,

derns, who perceived the Actions of the Muſcles without being able to diſcover their Fabric, and for that Reaſon they have been always inſtable, or wandering in their Opinions.

§. 390. But to proceed; the ſolid Parts of the human Body are either moved by the *Impulſe* [1] of the *Humours* [2] which flow forcibly through them; or elſe they are moved by means of *Muſcles* [3] which are faſten'd to the Parts deſtin'd for Motion: but this laſt Kind of Motion ceaſes, when the Muſcle is either divided, broke aſunder, or corrupted; and this Motion is either *voluntary* [4], ſpontaneous, or mixed.

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[1] The Aorta receives two Ounces of Blood from the Heart in a ſecond of time, and expels as much through the Veſſels in the ſame Inſtant of time: and therefore the Motion of the Blood appears to be ſtrong and rapid; for the Strength of this Motion is evident from the Heat reſulting from that and the Attrition, ſince when the Motion of the Heart is removed, the Parts immediately become cold. But all this Attrition and Heat reſults from the Force and ſolid Fabric of the Artery; for the moſt fierce Horſe who foams with his Strength may be eaſily quieted in a few Minutes time without at all changing the Humours, but only by running him under Water, by which the Motion of the Heart and Arteries will be removed: and therefore this muſcular Strength did not reſide in the Fluids, but only in the ſolid Parts.

[2] Both the vital and the animal Fluids each of them concur to this Action: for when once the Motion of the Blood and Spirits through the

Nerves is ſuppreſſed, all the Power of the Solids is immediately deſtroyed.

[3] In order to point out any Object with the Forefinger, the Tendon of it is immediately extended, as one may plainly perceive, towards the Wriſt: but if the Muſcle does not act, the Finger will not be extended, and therefore the Motion of the Finger is from the Muſcle.

[4] For Example: Suppoſe the Influence of the Mind deſtroyed, which is neceſſary to produce the Motion of a Muſcle, as we find it is in a paralytic Patient, there will nevertheleſs be no viſible Alteration apparent in the paralytic Limb; but yet he will not be capable of moving that Limb at pleaſure, which is therefore from a Defect in the Muſcles. But this voluntary Motion of a Muſcle is very different from the natural Motion of its Fibres, which always endeavour to contract themſelves; for that contractile Force ſtill remains in the paralytic Limb, and even increaſes after Death, when all the Motions of the Muſcles are deſtroyed.

§. 391. All Muſcles are ſaid to act, when, being render'd *ſhorter* [1], they draw together, or preſs the ſolid Parts to which they are attach'd, or expel the Humours by their Preſſure.

[1] That the whole Action of a Muſcle conſiſts in this Contraction or Shortening, will be readily allowed by every one who has made the leaſt Obſervation of them, or who has but the leaſt Skill in anatomical Matters: for when the lower Jaw is relaxed, or let down, the Maſſeter Muſcle may be eaſily felt with the Hand; and in biting, it may be perceived to ſhorten and ſwell. Even when you

move any Part of the Body, as the Arm, all that you have done is the ſhortening of thoſe Muſcles which move the Arm; and the Length which is taken from the natural Length of the Muſcles in their ſhortening, is the exact Meaſure of the Motion of the Arm. But though there is another Claſs of Muſcles, which either contain or carry ſome Humour; yet there is no Difference in their Motion, for they are likewiſe contracted about their contained Humours, which they expel by that Contraction. Of this nature are the Heart, Inteſtines, Bladder, Stomach, and Arteries: for theſe have a Contraction in the living Animal different from that which they continue to exert after the Animal is dead.

§. 392. All the Difficulty therefore in this Caſe is to aſſign the *Fabric*[1] and contracting Cauſe of the Muſcle; one of which muſt certainly have a great Dependance on the other.

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[1] If we have but once an Idea of the Fabric of the Parts of the human Body, we have then alſo an Idea of all its Motions: for the moſt inquiſitive Phyſician does not ſearch after the moſt remote Cauſes, but thoſe only which are capaple of being immediately perceived by our Senſes. And he who has explained the proximate Cauſe, muſt be allowed to have given the whole Account. For Inſtance; the Body A ſtrikes upon the Body B, which was before at Reſt; I ſay, that the moving Body A is the proximate Cauſe in the Motion of the Body B, which is all that we enquire after. For by a Cauſe we underſtand a Being related to ſome Effect, which Cauſe being removed, the other relative Being, which we call the Effect, is alſo removed, and the Reverſe. What Perſon, in

order to explain the Action of a Razor, would take upon him an Enquiry, after the Manner in which the Steel or Iron was generated in the Earth, and in what Manner its component Particles were differently combined and figured? Certainly ſuch a Perſon would ſpend more than a ſhort Life in an uſeleſs and tedious Enquiry after a Chain of Cauſes and Effects.

§. 393. Every *ſimple* [1] Muſcle hitherto known conſiſts only of one fleſhy Belly and one Tendon, and may be again divided into other ſmaller Muſcles perfectly like itſelf, excepting the Difference of their Size; and even theſe ſmaller ones which compound the larger, may be again divided into ſtill leſs, plainly alike in all reſpects but in Magnitude; and indeed this Diviſion proceeds ſo far, that at laſt they become ſo incredibly ſmall, as to exceed all the Power of Imagination. But Reaſon tells us that there muſt be an End. Since then the laſt and ſmalleſt is *like* [2] the whole Muſcle, it muſt needs have its Belly and Tendon in the ſame manner as the larger, but muſt be called a muſcular Fibre, by an Aſſemblage of which is formed a Muſcle properly ſo called.

[1] *Lower* was the firſt Anatomiſt who oppoſed the ancient Opinion, which attributed but one Belly, one Head, and one Tail to every ſingle Muſcle, that is to ſay, two Tendons, and one fleſhy Belly. But he demonſtrated that every Tendon had its proper muſcular Fleſh, and that therefore two Tendons had likewiſe two fleſhy Bellies in

the ſame Muſcle. But in moſt Muſcles one Tendon is fixed to an immoveable Bone, and this is called the Head of the Muſcle; while the other Tendon, which is inſerted into the Part to be moved, is called its Tail. Indeed ſome Muſcles are excepted which have no fixed Point, ſuch as the Sphincters. And the Moderns divide other Muſcles into much ſmaller Portions, each of which is furniſhed with its fleſhy Belly and Tendon: and of this nature there may be near a dozen diſtinct Portions obſerved in the deltoide Muſcle, which *Ruyſch* has even ſeparated into thirty Muſcles. But even here the Diviſion does not terminate, but may be carry'd ſtill further; inſomuch that the whole deltoide Muſcle may be truly ſaid to conſiſt of one hundred and forty-four ſmall Muſcles, each of which has its diſtinct Tendon: for the Tendon of any Muſcle may be divided by Maceration into as many Parts as its fleſhy Belly, as the Experiment may be very well tried in the large pectoral Muſcle. But the temporal Muſcle is almoſt ſimple below, whereas above it is divided into above fifty Tendons. The Biceps of the Cubitus, and the Triceps of the Thigh, are very diſtinct Muſcles, which meet together in one Tendon; but they have as many diſtinct moving Cauſes, as they have diſtinct Muſcles. *Lewenhoec* has at length alſo applied himſelf to examine into the Muſcles with his excellent Microſcopes; and demonſtrates, that one ſingle muſcular Fibre ſplits into numberleſs other Fibrils barely by macerating in Water; and that one of thoſe Fibrils, which to the naked Eye appears to be ſimple and uncompounded, does nevertheleſs by the Microſcope appear to contain as many ſmaller Fibrils as the whole Muſcle itſelf did contain of the viſible Fibres, which appeared to be the ſmalleſt to the naked Eye. In the vaſt Muſcle of a Whale he ſeparated the Fleſh into Portions, theſe Portions into Bundles, and theſe laſt into Fibres, till he came to a ſingle capillary Fibre; and this laſt Fibre he found to be as it were a Compendium of the larger Muſcle, ſeeming as large, and made up of as many ſmaller Fibres to the Microſcope, as there ſeemed to be viſible Fibres in the large Muſcle. But from the largeſt of Animals he deſcended to the ſmalleſt, and obſerved that the Foot of a Flea was contained in a ſort of Caſe or Shell like that of a Tortoiſe, which being broke, the Muſcle ſtarted out which was the Author of ſo great a Motion, and which, though ſeemingly but one Fibre, could be nevertheleſs divided by a very ſmall Needle into leſſer Fibres, each of which contained numberleſs other Fibres, remaining equally diviſible with thoſe in the Muſcle of the large Grampus Whale, which weighed ſo many Pounds.

[2] Geometricians tell us, that ſimilar Figures may differ in Magnitude, but have equal Sides and Angles proportionable to each other; from whence we may conclude one of the leaſt muſcular Fibres, which we are capable of diſcerning, to be perfectly like the large Muſcle itſelf: for we always find a ſort of fleſhy Belly tumifying in the middle, and growing ſmall towards the Ends into little Tendons. In the Muſcle of the fighting Cock which ſtrikes the Spur, whoſe Tendon oſſifies, *Lewenhoec* obſerved many diſtinct ſmaller Muſcles into which he divided the large one, till they were at length as ſmall as a Hair of one's Head; and then again by dividing that Fibre under the Microſcope with a fine Needle, lacerating the cellular Membrane, by which they are connected together, he then found that one of the ſmalleſt Fibrils, which was no larger than the hundredth Part of a Hair, had exactly the ſame Appearance with thoſe conſpicu-

ous to the naked Eye. Hence therefore we may take it for a general and certain Rule, that the Action of a Muſcle is the aggregate Sum of the Actions of the ſeveral ſmaller Muſcles of which it is compoſed.

§. 394. From what has been ſaid therefore it is evident, that theſe Fibres (§. 393.) are neither *arterial* [1], venal, nor even lymphatic Veſſels, but of a very different Nature; being Organs much more minute than thoſe. *Query*, Whether they are *veſicular* [2], compoſed of a Chain of Bladders? or whether they are not formed in one continued Tract?

[1] The Fibres of the Muſcles could not have been well formed of Arteries of any of the Orders, even the remoteſt from the ſanguiferous Veſſels; ſince all the Arteries receive an uniform Motion from the equable and common Action of the Heart: and therefore upon this Principle all the Muſcles would have been ſubject to the ſame Motions in all Parts of the Body at the ſame time. Beſides this, they cannot be formed of the Veins correſponding to any ſuch Arteries, ſince their Minuteneſs exclude the red Globules of the Blood conſpicuous in theſe Fibres.

[2] Many of the modern Anatomiſts affirm, that the muſcular Fibres are compoſed of Bladders; which Notion they ſeem to have imbibed from the Contraction or muſcular Fibres by which they grow thicker: for every Fibre left to itſelf ſpontaneouſly contracts with a certain Force, as all other Bodies do by a certain degree of Cold, by which Contraction the Fibre is corrugated into a leſs Space. But it is not only a Property of the Fibres, but

likewiſe of all other Bodies to expand with Heat and to contract with Cold, which Appearances I have reduced to geometrical Calculation in the moſt compact Metals. It muſt alſo be obſerved, that all the longer Muſcles in the Body are divided into leſs by Innervations or tendinous Interſections, as we ſee in the recti Muſcles of the Abdomen: for without this Mechaniſm the Animal Juices muſt have been impelled with an infinite Force to inflate or cauſe ſuch a Muſcle to contract. The like Interſections are likewiſe viſible in the ſmaller muſcular Portions as well as in the Muſcle itſelf, and alſo in each ſmall Fibre as far as our Senſes are capable of extending; there are alſo many minute Fibrils interpoſed betwixt the Tendons which unite into one larger Fibre, and which ſeem to be a Sort of Bridles or Sphincters to confine the Fibre about which they are placed, but that this is their proper Action does not yet appear. By this means the muſcular Interſections being contracted, produce the Phænomenon of *Cowper*, namely, a Corrugation of the whole Muſcles into unequal Surfaces or Wrinkles like Bladders: but yet neither *Cowper* nor any one elſe could ever demonſtrate real Bladders in the Muſcles, notwithſtanding he by injecting the Arteries with Mercury, found it paſs into the Cells of the veſicular Membrane, which inveſts all the muſcular Fibres; and the only Veſſels which he could fill affording any Appearance of Veſicles, were the lymphatic Veins which contain Valves.

§. 395. Since therefore the Nerves which enter *every Muſcle* [1], together with the Arteries and Veins, are *judged* [2] to depoſit their *external Coat* [3], (§. 281, 282.) and to be then diſtributed through the whole Body of the Muſcle in ſuch a manner, that there is no aſſignable Point in which there is not ſome Part of a Nerve to be found: aud as thus all the Nerves vaniſh in the Muſcles; whereas in other Parts of the Body, the Extremities of the Nerves being as it were expanded form Membranes; (§. 283.) from thence we *conclude* 4, having a regard to the Nature of the ſmalleſt Nerves, (§. 274.) that theſe *Fibres* 5 (§. 393, 394.) are a very fine *Expanſion* 6 of the ultimate Extremities of the ſmalleſt Nerves, deprived of their Coats, hollow internally, and of the ſame Figure with the Muſcle (§. 393.), being filled with Spirits or nervous Juice, (§. 275, 276, 277, 291.) which Juice is derived into the Nerve from its Origin or Fountain the Brain and Cerebellum, by the continual Force of the Heart.

[1] In the Heart itſelf, which is a very ſtrong Muſcle, free on all Sides, and only continuous to its Sacculus the Pericardium, we may eaſily perceive what Parts enter into the Heart, from whence we may derive the Origin of its Fibres and the Cauſes of its Motion. But there are four large Veſſels, namely, the coronary Arteries or Veins, Fat, and cardiac Nerves: now if (according to §. 394.) from the former of theſe there are no muſcular Fibres ariſe, it will follow, that they muſt come from the Nerve, as will be more evident by the Reaſons offered at (§. 400 and 402.) nor is it any Objection that the Nerve is incredibly ſmaller than the Muſcle: for if we regard the true Bulk of the Muſcle itſelf, as conſiſting of mere Fibres, it is extremely ſmall; inſomuch that if all the Humours, Veſſels,

ſels, and Fat are removed, there will but a very ſmall Portion of fleſhy Fibres remain, as Dr. *Keil* has very well demonſtrated in treating on the Quantity of the Blood and Humours in the Body.

[2] If you ſtrip the whole Artery, Vein, and Fat from the Muſcle, what remains ſeems to be the Nerve. For when a Nerve enters a Muſcle it never comes out again, but is ſpent in the Muſcle itſelf in which it diſappears: nor is there any viſible Point of a Muſcle which is not both ſenſible and contractile or moveable. If you prick any Part of a Muſcle with the fineſt Needle in a Frog or any other Animal while living, it will tremble and be contracted, and even when the Muſcle is cut out it will alſo contract by irritating its Nerve with the ſame Needle, as hath been obſerved by the diligent Naturaliſt *Swammerdam*: and therefore in every viſible Point of the Muſcle there is ſome Part of the Nerve, but the Arteries paſs out of the Muſcle and are reflected back in the Veins.

[3] Every Nerve is covered with a Membrane at its Entrance into a Muſcle, which Membrane is either derived to it from the dura Mater, or from ſome Ganglion, either proper to itſelf, or common to ſeveral other Nerves. For ſince the eſſential Part of the Nerve which conſtitutes the proper Subſtance of it, is ſoft and like a Pulp, it was neceſſary it ſhould be ſecured and defended in its Courſe through the various Parts of the Body, by being covered with hard and reſiſting Integuments or Caſes, which they throw off when they come to that Part of the Body where thoſe Integuments are no longer wanted, that is, where the pulpy Subſtance of the Nerve itſelf is immediately to perform its Office. Thus the Integuments of the dura and pia Mater are continued with the Thalami of the

optic Nerves, or anterior Productions of the Medulla oblongata, which are extremely ſoft and fluctuating like a Pulp: but when they are continued into the optic Nerve, they are ſo firmly ſecured by the Meninges, that they form a very hard Body or Nerve, which at entering the Eye depoſits or throws off its external Integument derived from the dura Mater, which forms the Sclerotica of the Eye; and then the internal Integument derived from the pia Mater is immediately after expanded within the former, conſtituting the Tunica Choroides, from whence ariſes the Tunica Ruyſchiana. After the Nerve has thus depoſited its three Integuments, it becomes a Pulp which is expanded in the Form of a reticular Membrane called the Retina, and ſerves for the immediate Organ of Viſion to receive the Impulſes of the Rays of Light, and tranſmit them to the Senſorium. What has been here ſaid of the optic Nerve takes place in the Nerve of every Muſcle throughout the Body, as far as we can perceive; for the Nerves of the Muſcles ſpread their external Integument upon the whole Muſcle itſelf, while their internal Integument, together with their external, are ſucceſſively continued to all the ſmaller Fibres in the ſame manner, whoſe Origin from the Nerve we are not capable of demonſtrating to the Eye by reaſon of their Minuteneſs. Thus from the Diſtribution of the Nerve and its Integuments in this manner, are formed the Fibres which make the larger Part of each Muſcle.

[4] *Veſalius* had not Patience enough to attempt a Diſſection of all the cutaneous Nerves, which yet has been happily executed by the Induſtry of *Euſtachius*, as we may readily perceive by the twenty-firſt and twenty-third of his excellent Tables. *Vieuſſens*, in his incomparable *Neurographia*, has

alſo deſcended very minutely to the Termination of the internal Nerves, as well as thoſe of the Skin. But *Malpighi* demonſtrates, that the cutaneous Nerves being continued through the adipoſe Membrane, at laſt terminate in the Skin itſelf, where they are interwove with the Arteries and Veins in the manner of Leather; but at length their Extremities depoſit the hard Coat derived from the dura Mater, which ſerves chiefly to compoſe the Cuticle, under which the internal Coat of the cutaneous Nerves, derived from the pia Mater, is immediately expanded in the ſoft reticular Body of *Malpighi*, which is perforated by the pulpy Heads of the Papillæ, which are formed by the proper Subſtance of the Nerve itſelf for the Senſe of Touch. The Nerves of the ninth Pair terminate after this manner in the Papillæ of the Tongue. The Auditory Nerve is entirely changed into a ſoft mucous Membrane, which is ſpent in the Labyrinth and double ſpiral Canal. And therefore the ultimate Extremities of the Nerves in all Parts of the Body ſeem to be after the manner of a ſoft Membrane. But what we ſee ſo conſtantly obſerved by Nature in thoſe Parts which come under the Inſpection of the Eye, the ſame we may alſo reſonably conjecture to take place in thoſe Parts which are inviſible.

[5] The Smallneſs of theſe Fibres exceed all Belief. *Lewenhoec*'s Microſcope ſo magnified a ſingle Hair of the Head, that it ſeemed to be above an Inch Diameter; but even five hundred Hairs placed by the Side of each other, will not appear to the naked Eye to be of an Inch Diameter: and yet by the ſame Microſcope, one of the ſmalleſt Fibres of a Muſcle did not appear larger than a ſingle Hair does to the naked Eye; and therefore it was not above one five hundredth Part as large

as a Hair of the Head. But even here does not the Smallneſs of the muſcular Fibre terminate; for though it cannot be any further divided, yet it appears to be made up of innumerable ſmaller Fibres in the ſame manner as the Muſcle itſelf appears. Nor is it improbable, that if the armed Eye of *Lewenhoec* was a thouſand times ſharper, yet the ſame Obſervation would be continued, namely, the continual Diviſion of each Fibre into leſſer ones. For that the Senſe of Viſion is not capable of penetrating to the ultimate Fibres, may appear, inaſmuch as that Fibre is the immediate Organ of the Motion itſelf.

[6] A ſmall hollow Cylinder flatten'd into a Bladder, affords a very convenient Idea to explain the Diſtribution of a Nerve terminating in the ultimate Fibres of a Muſcle: But this Fabric is no more than probable, ſince it cannot be demonſtrated to Senſe any farther than it appears agreeable by Reaſon to the Uſes aſſign'd for it. But this in general is true, that every thing which either perceives or moves in the Muſcle, belongs only to the Nerve: and therefore every Muſcle, ſo far as it is an Organ of Motion, appears to be a Continuation of the Brain, Cerebellum, and ſpinal Marrow; and that there is a continual Flux of nervous Juice from thoſe Springs, namely, the Brain, Cerebellum, and ſpinal Marrow, into every Point moving the Muſcle. But the Principle of Senſe and Motion in the Muſcles, regulated or governed by the Influence of the Mind, appears to be derived from the Brain; while the Principle of vital Motion, which is not voluntary, reſults from the Cerebellum; and from the ſpinal Marrow again ariſe Nerves both for voluntary Motion and Senſation. Thus therefore there are Nerves derived from the Brain to the voluntary Muſcles, and

from the Cerebellum to the vital or involuntary Muſcles; as the Fabric of the Arteries, Veins, Membranes and Fat in the Muſcle, do not derive their Motion from themſelves, but from the Nerve only.

§. 396. Of theſe ſmaller Fibres united together are compoſed Bundles, which again have another *diſtinct* [1] Membrane by which they are inveſted and diſtinguiſhed, or ſeparated from the other Bundles of the like Size; which holds true as far as the Senſes can penetrate: but this diſtinguiſhing and connecting Membrane of the Fibres is cellular, repleniſhed internally with Oil, which is accumulated in quieſcent Animals, and conſumed by Exerciſe, ſerving to anoint, defend, and lubricate the Fibres; and that this Fat or Oil is ſupplied from the Arteries into theſe Cells, is evident from the Injection of Mercury, which finds a ready Paſſage the ſame way.

[1] Every Muſcle is cover'd with its proper Integument or Capſule of the cellular Membrane, by which it is diſtinguiſhed from the other Muſcles, and adapted to contract or move itſelf freely. Thus the Heart is included in the Pericardium, and the other Muſcles are each inveſted with their proper cellular Membrane, that the Skin might move freely over the Muſcles, and that the Muſcles themſelves might move freely over thoſe Parts which are placed beneath them. For if we cut through any Part of the human Body, the Order in which the Parts appear will be firſt the Cuticle, the reticular Body, the Skin itſelf, the adipoſe

Membrane,

Membrane, and next to that the Muſcles or their Tendons for moving every Part of the Body. Even the Cauſe of a free Motion of a Muſcle depends in a great meaſure upon the adipoſe Membrane with which it is on all Sides inveſted: for in the ſame manner as the Panniculus adipoſus is expanded under the Skin throughout the Body, ſo it alſo inveſts every particular Muſcle, and even every individual Faſciculus of its muſcular Fibres, of which there are great Numbers; as, for Inſtance, in the dethoide Pectoral and glutei Muſcles. Laſtly, It farther extends betwixt every individual or ſingle Fibre of which the Faſciculi are compoſed, of which ſingle Fibres there may perhaps be ſome Myriads entering the Compoſition of a large muſcular Fibre, which is viſible to the naked Eye; and thus largely is the cellular Membrane expanded about every Fibre and Veſſel, as appears from the Obſervations of *Lewenhoec.* That curious Gentleman cut off a ſmall Portion of the Muſcle of an Ox which had been dried in the Smoke, and placed it under the Microſcope; and he found that it reſembled Windows of yellow Fat, betwixt which there were ſome of the red muſcular Fleſh interpoſed. If you inſpect the Muſcles of a Hog before fattening, they will appear quite red, with little or no Fat; but if the Muſcles of the ſame Hog are examined about Autumn, againſt which time they are fed, it will be twenty times as large as before, and exhibit but very few red Fibres, betwixt which will be interpoſed little Bags full of Lard, inſomuch that nineteen Parts out of twenty in the Muſcle are made up by the cellular or fat Membrane. But this Oil ſerves, firſt, to render the Fibres flexible and eaſily ſuſceptible of their Contractions and Dilatations. 2. It prevents one Fibre from growing to the other, and hinders the

Muſcle itſelf from adhering to the adjacent Parts. 3. It abates the violent Heat and Attrition of the Blood, and prevents its Acrimony; inſomuch that there is no Fat but in Parts where ſome Attrition is to be taken off, or ſome Acrimony mitigated. The more frequently any Muſcle is put in Action, the more Fat is it uſually cloathed with; as, for Inſtance, in the Glutei, abdominal and pectoral Muſcles. If this Fat, which inveſts and diſtinguiſhes each Muſcle, and the ſeveral Parts of the ſame Muſcle, be conſumed or deſtroyed by Suppuration, the motion of the Part is then deſtroyed, while the Fleſh of the Muſcle itſelf is not touched. Thus, after Abſceſſes, when the Fat has been conſumed which ſeparated the Muſcles from the Skin and adjacent Parts, they will all cohere together, ſo as to deſtroy the Motion of the Part, or make a ſtiff Limb. This I have experienced in myſelf, by burning my Thumb in making ſome chymical Experiment; for the Skin adhering to the adjacent Muſcles, occaſioned a Rigidity or Stiffneſs in the Motion, notwithſtanding the Wound was perfectly cured; nor can I get rid of it by the Uſe of any Fomentations.

§. 397. But an *Artery* [1] is alſo diſtributed through every Muſcle, in which its Branches are found ſo large, numerous, and interwove in ſuch a manner, that a Perſon who is *not cautious* [2] would judge the whole Body of the Muſcle to be compoſed of that Veſſel only. Theſe Arteries are diſtributed chiefly betwixt the Faſciculi of Fibres (§. 396.), and in the Membranes which diſtinguiſh them from each other, and perhaps alſo upon the external Surface of every individual Fibril (§. 393.); in which Places they terminate in reticular Plexus's, ſecretory Oil Ducts (§. 396.), ſmall or lymphatic Arteries, and perhaps into hollow Fibres *like* 3 Nerves; and theſe laſt hollow Fibrils may alſo terminate either in the hollow muſcular Fibres derived from the Nerve (§. 393, 394.), or elſe they may themſelves conſtitute Fibres of the like nature.

[1] *Euſtachius* has very well expreſſed theſe Arteries in his Figures of the twenty-fifth and twenty-ſixth Table. But they are uſually diſtributed through the Muſcle in ſuch a manner, as to run according to the Courſe of the Fibres. Theſe Arteries are very large in the Muſcles of the Abdomen, and there are not inconſiderable ones even in the Tendons themſelves.

[2] *Ruyſch* happily injected the coronary Arteries ſo far that an unwary Perſon might be eaſily perſuaded that almoſt the whole Heart was a Heap of Arteries: but in this Preparation Part is deſtroyed, and Part of the vaſcular Syſtem remains unfilled, eſpecially by Maceration, in which thoſe Veſſels are diſſolved where the Injection has not penetrated; while others of the Veſſels are compreſſed, ſo that by the Expanſion of thoſe which are injected, the empty Cells, Nerves, *&c.* are obſcured. But theſe Arteries are diſtributed alſo in part upon the Cells of the adipoſe Membrane for the Separation of the Fat; and perhaps they may be alſo diſtributed in the ſame manner upon the ultimate ſmall Cells or Cylinders of the nervous Fibres themſelves. But it ſeems reaſonable, that as a ſufficient Quantity of Arteries enters the Muſcle to compoſe the arterial Syſtem, and conſiderably increaſes the Bulk of

that Organ; ſo the Nerve expands itſelf into as many Branches as are neceſſary to compoſe the nervous Syſtem of the ſame Muſcle. If we examine the Heart when its coronary Arteries are injected, as alſo the cardiac Nerves in their Diſtribution through the ſame Muſcle, we ſhall perhaps reaſonably conclude, that there is no great Diſparity betwixt the numerous Ramifications of each, conſpiring perhaps to aſſiſt the Action of each other.

[3] The ultimate or ſmalleſt Veſſels which convey the moſt thin nutritious Humour, are here intended. We are not capable of diſcerning the ſmalleſt Arteries by the Eye, unleſs perhaps ſome of them which are as large as ſmall Threads: but the ſmalleſt Arteries in the cortical Subſtance of the Brain, terminate at length into inviſile Arteries, which themſelves open into the ſmaller Tubuli of the Medulla. But if this Mechaniſm takes place in the Brain, why may it not alſo obtain in other Parts? eſpecially where the Arteries become as ſmall as thoſe in the Brain and Cerebellum, being little or nothing larger than the Tubuli of the Nerves themſelves.

§. 398. At leaſt it is evident, that every Branch of an Artery in a Muſcle is furniſhed with correſponding *Veins* [1], which uniting form a larger Vein, whence the ſanguiferous and *lymphatic* [2] Veſſels of a Muſcle are derived.

[1] If the Veins are exactly filled with ceraceous Injection, they will in a manner ſeem to compoſe the whole Subſtance of the Muſcle. In the Heart there are innumerable Veins which open into the Vena Cava; into the right Auricle and the ſame

Ventricle; but the Diviſion or Diſtribution of all the Veins is always anſwerable to the Ramifications of the Arteries.

[a] There are many Anatomiſts unwilling to allow that the Muſcles have any lymphatic Veſſels. But if there are Arteries, there muſt neceſſarily be returning Veins: but that there are Arteries of the ſmaller Series in Muſcles, is evident from a Repletion of them by Injections, which enter ſmaller Veſſels than thoſe naturally deſtin'd for red Blood; and therefore it will follow, that they muſt be accompanied with Veins for returning the ſubtle Humours of thoſe ſmall Arteries again into the Blood. The Nerves themſelves do not terminate in blind Extremities which are not pervious; but they exhale continually ſome Part of their Contents, and others diſcharge their Contents into correſponding Veins (§. 292.): which Veins diſcharge their Contents into the ſmaller and larger Lymphatics. Even there is no great Difficulty in demonſtrating the lymphatic Veſſels of a Muſcle by Experiment: for if the ſubclavian Vein be tied in a living Dog, and then a ſecond Ligature made further on towards the Arm, the Courſe of all the Lymph flowing from the Head, Thorax and Abdomen to this Part will then be ſtopped: and if you diſſect the Dog after Death, you will perceive innumerable lymphatic Veſſels, not otherwiſe conſpicuous, ariſing from all Parts of the Body. *Nucke* has alſo demonſtrated Lymphatics in the Heart, and figured them in various Parts of Animals which he has prepared, which I have frequently contemplated with much Pleaſure while that Anatomiſt was living.

§. 399. But the Tendon of a Muſcle being ſtrictly examined, divides itſelf into as many

Fibres [1] as there are in the Muſcle itſelf; but with this Difference, that the Cavity of a muſcular Fibre, diminiſhing from its obtuſe Belly, conjoins together into one accumulated Body, which is *ſtronger* [2], harder, drier, narrower, and almoſt deſtitue of viſible Veſſels, notwithſtanding the ſmall Veſſels here appear innumerable and diſtinct by the *Ruyſchian* Art of *injecting* [3], and diſtributed throughout every Point of the Tendon; and from a ſtrict Combination of theſe accumulated Ends of the Fibres, the whole Tendon of the Muſcle is formed, and may be very properly termed *Aponeuroſis* [4], or an Addition to the Nerve, though the Name was given upon another Occaſion. Of two ſuch Muſcles (§. 392, to 399.) connected in oppoſite Directions, almoſt all the larger viſible Muſcles are formed.

[1] The deltoid Muſcle may be readily divided into twelve ſmaller Muſcles *(per* §. 392.*)*; but to theſe twelve ſmaller Muſcles, there are alſo twelve correſponding Tendons united. But the Diviſion may be again continued in the ſame Muſcle almoſt to any Degree, inſomuch that it will remain diviſible as long as the Senſes can trace it. And as the fleſhy Belly of each Muſcle, and its ſeveral Fibres, are covered each with their diſtinct Membrane; ſo likewiſe are the white Veſiculi and Fibres of the Tendons themſelves: the Number of Veſiculi and Fibres in the Tendon correſponding to the fleſhy Fibres of the Muſcle; ſo that there is not any fleſhy Fibre, but what has its correſponding Fibre in the Tendon. One may even truly ſay, that the Muſcle is the Tendon dilated,

and that the Tendon is the Fleſh of the Muſcle contracted; ſince the Fibres which were very diſtant from each other in the fleſhy Belly of the Muſcle, run together into cloſer Contact and Coheſion in the Tendon. In the fleſhy Part of the Muſcle the Nerve is a dilated Membrane, but in the Tendon it is a contracted Membrance deſtitute of any Cavity, and is ſo much harder or more compact in the Tendon than it was in the Fleſh, as the Tendon of the Muſcle is ſmaller than the Muſcle itſelf.

[2] The Tendo Achillis ſuſtains a thouſand Weight without breaking: and it is a common thing for the Butchers to ſuſpend the whole Ox upon Hooks paſſed through theſe Tendons.

[3] A ſmall Segment of an injected Tendon appears perforated with many Veſſels, which are divided by the Knife. *Ruyſch* macerated a Muſcle for ſome time in pure Water, and then injected its Veſſels after his manner, which he kept ſecret; and then upon cutting off the Tendon from the Bone, it appeared elegantly painted with a red Colour, inſomuch that I have manifeſtly obſerved both the red Arteries and cellular Membrane placed about the Fibres of a Tendon, which was prepared by *Ruyſch*.

[4] The whole Muſcle is compoſed of Faſciculi, which are reſolvable into ſmaller Portions or Bundles; and the ſame Diviſion may be continued further by the Microſcope, when the Eye itſelf can no longer ſuffice. It may be therefore reaſonable to ſuppoſe, that what obtained in the large Part of the Muſcle may alſo take place in like manner in thoſe of the Tendon; and as the Muſcle conſiſts of nervous Threads, which do not touch each other, but are diſtinguiſhed or ſeparated by the Intervention of Arteries, Veins, and a cellular Membrane:

therefore the like Fibres or nervous Threads are continued only at a leſs Diſtance from each other in the Tendon; whence the Ancients properly enough called the Tendon Aponeuroſis, which is as much as to ſay, a Production or Continuation of the Nerve.

§. 400. The *red* [1] Colour of every Muſcle therefore proceeds from its contained Blood, which being waſhed out, the Muſcle looks pale. But the Bulk of a Muſcle depends on the Repletion of its Arteries, Veins, and oily Cells; as alſo more eſpecially the Repletion of its lymphatic Veſſels. Hence therefore ariſes the *Leanneſs* [2] or Atrophy which accompanies old Age. And from hence alſo it is that the Muſcle ſhrinks ſo much by an accurate *waſhing* [3] of it, or by long boiling. And yet we ſee, that in old Age an *Atrophy* [4], and in thin Habits; that the Muſcles retain their Motion; and that this Motion may be performed in Muſcles which are not red, is evident in *Inſects* [5] which have no viſible red Fleſh.

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[1] When Water is injected through the coronary Arteries, in order to make a Preparation of the Heart, it returns through the Veins at firſt bloody, afterwards more dilute, and at length quite lympid, till the Heart itſelf appears white, but entire, and without any Alteration of its Structure. But even without this anatomical Preparation, thoſe Muſcles which are almoſt perpetually exerciſed with Motion, look naturally pale and colourleſs, ſuch as the Stomach, Inteſtines, Urethra, Bladder, *&c.*

[2] Oxen which are brought from the North in the Month of *February*, do in the ſpace of another Month become Fat. I viſited a Patient afflicted with the Colica Pictonum, which is a wonderful Diſeaſe uſually terminating in a Palſy; but the Muſcles in this Patient were ſo much waſted, that there was a Cavity betwixt the Radius and Ulna ſufficient for one's Finger to be contained; and in ſhort, he ſeemed in all reſpects a Skeleton cover'd with Skin. But yet there is ſome Hopes that he may recover, and there are more than a few that I have cured in this Condition; which is a manifeſt Sign, that in ſuch a State there is every thing remaining which is neceſſary to the Muſcle. In old Age the Cheeks and Calf of the Legs fall away, the Skin becomes wrinkled, and the Muſcles in a manner diſappear.

[3] *Steno*, by long macerating the Heart in warm Water, then boiling it, and again macerating for a conſiderable time with warm Water, diſſolved that Muſcle into Fibres ſo minute, that they ſeemed to reſemble Smoke or Vapour: but by this Preparation the Bulk of the Heart is ſurpriſingly diminiſhed, nor does it preſerve its natural Fabric. The Bulk therefore of the Muſcles denotes the Degree of their Diſtention or Repletion of their Arteries, Veins, lymphatic Veſſels, and oily Cells. But that Part of the Muſcle upon which its Motion depends is very different from the Artery, Vein, Nerve, or cellular Membrane; nor is there any Oil nor red Blood required to produce this Motion.

[4] An Atrophy is a Diſeaſe that only conſumes the Fat and Lymph, leaving the Structure and Action of the Muſcles: thus it is with very lean Horſes that are violently exerciſed. A phthiſical Patient who was almoſt conſumed, did nevertheleſs

leſs eaſily and readily move all the Muſcles of his Body. I ſaw an ingenious *Engliſhman*, who was returning from *France*, ſo much conſumed by an Atrophy, that only the hard Bones remained, and all the Fat was even waſted in the Orbits of his Eyes: yet he could talk very diſtinctly, and moved his Fingers very exactly; ſo that the Parts in the Muſcle which perform its Motion, may remain when the Muſcle itſelf is almoſt reduced to nothing; for the ſolid Fibres in a Muſcle are not injured in a Conſumption; and therefore all the Parts of the Head, the Encephalon and ſenſitive Organs continue perfect to the laſt.

[5] The Flea which moves ſwifter than any other Inſect, has nevertherleſs its Muſcles which move the ſaliant Legs of the Inſect of a white Colour, and their Structure appears the ſame as in the Grampus Whale, which is as vaſt an Animal as a Flea is minute.

§. 401. The Fibres (§. 393, 394.), the Faſcicul of them (§. 396.), the Arteries (§. 397.), and the Nerves (§. 395.), are all diſtractile or capable of Elongation without breaking both in the living and the dead Animal, notwithſtanding they are continually in the State of *Tenſion* [1], and endowed with a Power of *contracting* [2] themſelves; for being cut aſunder, they contract and ſhorten very much, diminiſh in Bulk, and draw themſelves up into a ſort of wrinkled Surface, while their contained Juices are at the ſame time *expelled* [3]; hence therefore they appear to be continually kept in a State of *Violence* [4] or Diſtention, with reſpect to themſelves, always reſiſting Elongation, and always endeavouring to contract or ſhorten themſelves; but this much more in the living than in the dead Animal, and therefore one Muſcle requires to have this *antagonized* 5 by another Muſcle acting in a contrary Direction.

2. If the *Brain* 6 be violently compreſſed, contuſed, totally obſtructed, ſuppurated, or cut out in ſuch a Manner as to let the Injury extend into the Medulla, then the Actions of all the voluntary Muſcles ceaſe inſtantly, together will all the Senſes and Memory; but on the other hand, the ſpontaneous Motions of the involuntary Muſcles ſtill continue both in the Heart, Thorax, Veſſels, Viſcera, and vital Parts; but nothing of all this happens when the Brain which is opened remains free and ſound.

3. If the ſame Injury (N°. 2.) be offered to the *Cerebellum* 7, the Action of the Heart immediately ceaſes, together with all the Senſes, voluntary Motions, Reſpiration, and Life itſelf; but a vermicular Motion remains a long time after in the Stomach and Inteſtines, which may be again *reſtored* 7 in theſe Parts after it has ceaſed, and when theſe Injuries are removed in time.

4. If the *Nerve* 8 of a Muſcle (§. 395.) be compreſſed, tied with a ſtrict Ligature, corrupted or cut aſunder, all the vital and voluntary Motions of that Muſcle is then quite aboliſhed; and if the Trunk of a Nerve is injured in the ſame manner, ſupplying its Branches to different Muſcles, they will all of

them be in like manner deprived of their Motion; but the Injury being removed without deſtroying the Continuity of the Nerve, the Functions of all the Muſcles return as at firſt.

5. The ſame Injury being offered to any Part of the *ſpinal Marrow* [10], then the Action of all thoſe Muſcles is deſtroyed, whoſe Nerves ariſe from the ſpinal Medulla below the Part affected, while the Actions of thoſe remain intire, which have their Nerves from above.

6. If the like Injuries are offered to an *Artery* [11], diſtributed to one or more Muſcles, all the ſame Conſequences follow.

7. The *Tendon* [12] of a Muſcle in *Action* [13] (§. 399.) receives ſcarce any Alteration that is ſenſible; but the fleſhy Belly of the Muſcle (§. 393.) is much *ſhortened* [14], grows hard, pale, turgid, and protuberant or ſwelled, while the Tendons approach towards each other; and thus is the Part to which the Tendons are connected, drawn towards the other Part which is *leſs moveable* [15]; which Action is called the Contraction of a Muſcle, being much more conſiderable and ſtronger than the other natural contracting Force of the Muſcle mentioned at N°. 1.; and therefore this is not the natural, but acquired Force of a Muſcle.

8. The Tendon of a Muſcle out of Action continues the ſame as before; but the Fleſh of a Muſcle becomes *longer* [16], ſofter, *more red* [16*], ſhrunk or *collapſed* [16**] and flattened; and this State is called the *Reſtitution* [17] of a Muſ-

cle to its natural Condition, though it is moſtly performed by the Force of the *Antagoniſt* [18] Muſcle; for the Antagoniſt remains flaccid, or unactive; the contracting of the other Muſcle will continue of its own accord from the innate Force (N°. 1.) prevailing, without being counterpoized.

9. If one Antagoniſt Muſcle acts (N°. 7.), while the other remains unactive, and in the Condition of N°. 8. in that Caſe an Inflection of the Limb follows ſpontaneouſly; but if both of the Muſcles act at the ſame time, it is then held immoveable; if neither of them act, the Limb remains ſlack and indifferent to Motion, in ſuch a manner that the leaſt Exceſs of Force in either of the Muſcles, made either by Subtraction or Addition, will incline the Limb its own way.

10. But theſe Changes (N°. 7, 8, 9.) are made alternately, even in a *Moment* [19], or the leaſt ſenſible Inſtant of Time, in the whole Fleſh at once throughout the whole Muſcle; and thus are they reciprocally abſent and preſent, without leaving any remaining Signs behind them.

11. *Warm Water* [20] injected into the Artery of a Muſcle at Reſt, or in a dead Animal, either produces or renews its Contraction, even though the Experiment be tried a conſiderable time after Death.

12. The Bulk of a Muſcle in Action appears rather *increaſed* [21] than diminiſhed in all Experiments whatever.

13. The Limbs being bent by an *external Force* [22], even againſt the Inclination or Will, cauſes the flexor Muſcles to put on the State of contracting or ſhortening (N°. 7.) in the ſame manner as if they acted by their own proper Motion, only with a leſs Force.

14. While the Will remains *undetermined* [23], all the *voluntary* [24] Muſcles remain equally full in all their Veſſels, and equally diſpoſed for Motion by the Blood and Spirits, which are equally diſperſed throughout every Part of the Body at one and the ſame time.

[1] Every Artery, Vein, and muſcular Fibre in a living Animal, with all the Membranes, are attached to ſome Bones, by which they are ſtretched out or ſuſtained in a State of Tenſion, ſo that upon a Diviſion of them either in the living or dead Animal, they fly back or recede from their mutual Contacts, ſo as to form a Space immediately after the Knife has paſſed through by the Retraction of each Fibre towards its Origin. I have often obſerved this Contraction to a ſixth Part of the length of ſome Fibres. Hence we are taught that all the Fibres are maintained in a more diſtracted or tenſe State, while they continue faſtened to the Bones, than when they are cut off the Body; and we alſo learn, that at which ever End a Fibre or Muſcle is divided, it will contract towards that End which remains entire, whether we ſuppoſe the ſame to be its Origin or Inſertion. But that this contractile Force of a Muſcle is not inconſiderable, may be demonſtrated by Experiment: for if a Muſcle be laid bare in the Thigh of a dead Dog, and a Weight faſtened to the ſame Muſcle, upon dividing the Tendon, the Weight will be

raiſed by the ſpontaneous contractile Force of the Muſcle, by which it endeavours to become ſhorter than its natural Length; and this Phænomenon is obſervable in all the Fibres contained in every Part of the Body. But an animal Fibre may be extended much beyond its natural Length, and afterwards it will contract and recover its former Shortneſs, as is evident in Fiddle-ſtrings, which are uſually made of the Inteſtines of the ſmaller and more active Animals, ſuch as Cats Dogs, *&c.* being firſt well cleanſed from all their Fat or Oil. Such a String or Cat-gut well twiſted and prepared will ſuſtain an immenſe Weight before it breaks: but if at length it breaks, the divided Parts immediately fly towards each End, and the whole String becomes much ſhorter than it was before. But it is not neceſſary to break the String, in order to obſerve its Contraction; for upon removing the extending Weight, or diminiſhing it to any Degree, the String will ſhorten proportionably. For Inſtance: If you ſuſpend an hundred Weight to a very ſtrong Cord of this nature, and then take off the Weight of one Pound, the Cord will ſhorten one hundredth Part of the Length which it acquired by the Weight; and upon removing another Pound, it will ſhorten as much more, and ſo on in proportion to the Diminution of the Weight; but yet ſo as to remain tenſe, as long as there is the leaſt appended Weight, becoming ſhorter when all the Weight is removed. This contractile Force is poſſeſſed by all Cords or Threads, and ariſes neither from the Air, Heat, Gravity, or any external Power, but only from the ſimple and mutual Attraction of the Elements or Particles which compoſe the Thread, whoſe Force is overcome by the extended Power of the Weight; upon removing which, the diſtracted Elements

Elemeents approach nearer to each other by the ſame Force. Almoſt in the ſame manner we ſee that two Loadſtones being drawn from each other by any Weight, while they remain within the Sphere of Activity, upon removing the Weights, they will mutually approach towards each other.

[2] For the Elements or conſtituent Particles of each Fibre, do all approach nearer to Contact with each other; ſince every diſtracted Body increaſes its Surface without increaſing its Quantity of Matter; and when again the Diſtraction is taken off, the Parts by contracting recover a cloſer Contact, and diminiſh their Surface or Bulk, tho' the Quantity of Matter remains the ſame.

[3] In the dead Body or Subject which lies under the Hand of the Anatomiſt, all the Fibres and Veſſels contract themſelves, and expel their contained Juices. The Arteries are ſo much diminiſhed in their Diameters after Death (§. 213.), that there is no Compariſon betwixt them and thoſe of a living Animal; and they appear to contain a much thicker and darker-coloured Blood, while they expel their Lymph and thinner Juices into the Veins, ſo as to appear almoſt empty; whereas in the living Animal they are always full. For the Arteries contract in proportion to the Quantity of their contained Humours which is evacuated, and they conſtringe themſelves about the Remainder of their Contents. The Stomach, Inteſtines, and thoracic Duct, all continue to propel forward their contained Liquors even after Death. In an Apoplexy ariſing meerely from a Deficiency of the Vis Vitæ, or Removal of the Force of the Heart, while all the Viſcera remain entire; as alſo in a Swoon Life will be reſtored, if the Humours or any Liquors are forced through the thoracic Duct.

[4] We call any State or Condition of a Body violent, in which it ſuffers ſome Alteration or Change by the Action of another Body; and the natural State we ſuppoſe to be the Condition which the Body acquires of its own accord, when left to itſelf; and from hence we are able to demonſtrate, that all the Muſcles, of the human Body are conſtantly in a State of Violence. For the Fibres, Veſſels, Membranes, and other ſolid Parts are extended by their Attachment to the Bones, and therefore they continually endeavour to contract themſelves into a ſhorter Compaſs. The whole Length of the human Body is determined by the Bones, when they are ſufficiently firm; but when they loſe their Reſiſtance, all the Parts ſhorten. The *French* Surgeon *Saviard* remarks, in the Obſervations which he made in the Hoſpitals of *Paris*, an Inſtance of a Man whoſe Bones became by degrees ſo flexible, that towards the latter End of the Diſorder the Radius and Ulna were as flexible as a Piece of Whale-bone; the Diſorder was attended with immenſe Pain, for the Perioſteum muſt neceſſarily be ſubjected to violent Diſtentions in the bending of the Bones, until that Membrane is broke through, in the ſame manner as when the nocturnal Pains are formed in the venereal Diſeaſe by Nodes in the Bones. Upon opening the Body, the Bones appeared like ſoft Cheeſe, as if they had been boiled in *Papin*'s Digeſtor; and inſtead of Marrow, they contained a watery and bloody Juice. From this Inſtance it appears, that the Fibres of the Muſcles continually endeavour to ſhorten and inflect the Bones, which would certainly follow, if they had not that Hardneſs which is ſufficient to reſiſt the Contractions of the Muſcles. Even the Eye itſelf demonſtrates a contractile Power, ſince after Death it appears contracted into

Wrinkles, whereas before it was ſmooth and extended. But yet our Senſes do not perceive this Endeavour of all the Parts to Contraction, becauſe it is equally diffuſed throughout every Part, and the Equilibrium of it is not deſtroyed ſo as to break out into Motion. Suppoſe the Force of any Muſcle by which it contracts itſelf to be equal to a hundred, and the diſtending Force which oppoſes its Contraction to be equal to two hundred, it will not therefore follow, that the Muſcle does not continue to act with the Force of a hundred, becauſe we do not perceive that it overcomes the Reſiſtance of two hundred by which it is oppoſed; but if you remove the Reſiſtance of the two hundred, the Muſcle will continually contract itſelf, not by any additional Force, but by the Power which it before exerted in Oppoſition to two hundred. For Inſtance again in the Weight of a Pound; if it falls upon a Table, it will not reach the Ground; but yet its Gravity continues to act, and it endeavours to reach the Ground with the ſame Force which it received from the Motion; but if you remove the Table without giving the Weight any Impulſe, it will inſtantly fall to the Ground, not by any new Force, but by the ſame Impulſe of Gravity, by which it before endeavoured to deſcend. Suppoſe again an exquiſite Balance has a thouſand Pounds in each Scale, they will be ſuſtained in Equilibrio by the Equality of the contrary Forces, ſo that neither of them will deſcend; not becauſe the Weights do not exert the ſame Force to cauſe them to deſcend, but from the Equality of the contrary Powers deſtroying each other. If again you caſt but a ſingle Grain of Sand into one of the Scales over and above the other Weight, it will deſcend and overcome the Power of its Antagoniſt, not from the Weight of the Grain of

Sand, but from the Inequality which it makes betwixt the two Powers.

[5] Every Muſcle is provided with its Antagoniſt, except where the Elaſticity of the ſolid Parts is ſufficient to equal their Reſiſtance or contractile Force, of which we have an Inſtance in the Intercoſtals but the Effect in both Caſes is the ſame. If it was not for this Equality in diſpoſing of the Muſcles, the Figure of a Limb could never be changed from the Poſture which it before obtained, and a Limb once bent or extended would continue ſo as long the Perſon lived. But the antagoniſt Muſcles are ſo diſpoſed in Equilibrio, that a Motion may be readily produced and governed in every Part of the Body by the Influence of the Mind, either by adding to or diminiſhing the Force of any one Muſcle. But the Reaſon of this Mechaniſm does not appear evident to all. We think a Man is at reſt, when at the ſame time all the Muſcles in his Body are in a continual Tendency to Motion; and yet none of the Limbs are moved, becauſe the inflecting Powers are oppoſed by thoſe which extend, and there is no Force exerted in one Part but what is oppoſed in another. When the extending Forces act with the Momentum of a hundred; and there is alſo at the ſame time a Momentum equal to the ſame Number exerted by the inflecting Powers, it will therefore follow, that the Limb will be retained immoveable by the Equality of the oppoſite Forces, which, though conſiderable, deſtroy each other by their Equality and Contrariety. From hence we may be able to underſtand the Propoſition which may at firſt ſeem a Paradox, namely, to increaſe the Motion of a Body by diminiſhing the moving Powers. In the extended Finger all the Parts ſeem to be at reſt, when at the ſame time a powerful Motion remains

in the Muſcles, which govern that Finger: and this occult Motion in the Muſcles will become manifeſt upon dividing the ſeveral Muſcles, and leaving only one Flexor intire, for in that Caſe the Finger will be continually inflected without making any Addition to the inflecting Power. If the Force of ſome Muſcles is deſtroyed by a Palſy inſtead of the Knife of the Anatomiſt, the flexor Muſcle will in the ſame manner act as before. Suppoſe a Man ſleeping with his Arm bent in an Angle; in that Man four ſtrong Muſcles act equally upon the Cubitus, namely, the Ulnaris Internus, the Radialis Internus, the Ulnaris Externus, and the Bicornis; ſo that there is a conſiderable Force exerted here towards Motion without producing any Effect. Suppoſe again one of the extenſor Muſcles to be rendered paralytic, ſo as to deſtroy a fourth Part of the Force which acted upon the Cubitus, it will in that Caſe be certainly moved or inflected. For ſince the inflecting Powers remain the ſame, and act with the Force of two, while, the extending Force is equal to no more than one, the Flexor will therefore overcome the ſingle Extenſor and move the Limb, in proportion to the Deficiency in the extending Force. If an external Muſcle becomes paralytic while the internal one is not affected, in that Caſe half of the moving Force being taken off, an Inflection of the whole Limb will follow, ſo as to produce a very viſible Motion, when at the ſame time a Diminution is really made in the moving Powers.

[6] A Bull which is one of the fierceſt and ſtrongeſt of Animals, being firſt ſecured with Ropes, and then knocked on the Head with an obtuſe Inſtrument, there follows a Rupture in ſome of the ſmall Arteries of the Brain, by which the Blood is extravaſated, compreſſes the Encephalon, and the Animal tumbles down in a Moment with a Palſy of all

his Limbs, expiring ſoon after. If the Head of the Animal be opened after Death, you will find the ruptured Arteries which extravaſated their Blood by the Impetus of the Blow; and therefore it was this Blood which compreſſed the Brain and produced the Stupidity and Death of the Animal. In one of the more frequent Cauſes of Death, like the former, namely, in an Apoplexy, the Blood-veſſels are ruptured, the Blood extravaſated, and the Brain itſelf compreſſed, whereupon all the Senſes and voluntary Motions are aboliſhed, the Body tumbles down paralytic, the Perſon ſeems in all Reſpects as in a deep Sleep, and in a little time after that Sleep Death itſelf follows. There was a Man at *Paris*, who may be perhaps yet living (*An.* 1727.) who went about begging with Part of his Brain expoſed, having loſt a conſiderable Piece of his Skull; and by giving this Perſon a Bit of Money, he would condeſcend to let the ſame Experiments be tried upon him which a Preſſure uſually produces in the ſeveral Diſorders of the Brain. By a ſlight Preſſure the Eyes were obſerved to look red, and he then imagined he ſaw Sparks and Flaſhes of Light, at length Stupidity followed, and laſtly a deep Sleep with a Stertor as in an Apoplexy: and by the ſame degrees did this Perſon return to his Senſes and the Uſe of his Limb, ſo ſoon as the Preſſure was removed from the Dura Mater.

[7] *Duverney* made ſeveral judicious Experiments; he opened the Cranium of a living Dog, compreſſed the Brain, and obſerved that a ſudden Apoplexy followed, attended with the Loſs of all the Motions in the voluntary Muſcles: and then making an Inciſion through the Dura Mater, he compreſſed the Cerebellum, whereupon the Death of the Animal ſuddenly followed, except only that the Heart continued to palpitate for a little time;

and this we know it will do even after it has been taken out of the Body. Hence therefore we manifeſtly perceive two Springs of Motion in the Muſcles: ſince the voluntary Muſcles, which are directed by the Influence of the Mind, become paralytic by compreſſing the Brain, from whence therefore their Nerves muſt be derived; but the involuntary Muſcles, as the Heart, Stomach, Inteſtines, and thoſe of Expiration, continue their Action while the Brain is compreſſed, but are all immediately rendered paralytic, when the Cerebellum itſelf is injured; and therefore theſe laſt muſt derive their moving Powers from the Cerebellum. I had an Opportunity of ſeeing both theſe Caſes in continual Apoplexies: one in a Perſon who came to the *Hague*, and immediately upon ſetting his Foot out of the Boat, he fell down inſtantly dead; the other in a Grinder, who fell down apoplectic in the ſame manner, but his Pulſe and Reſpiration continued, with a Snoring and Redneſs of the Face; and by Phlebotomy, with a thin Diet, he perfectly recovered in a few Days time. Thus, in the firſt Caſe, the extravaſated Blood immediately compreſſed the Cerebellum, whereas here it only compreſſed the Cerebrum.

[8] It has been ſaid before, that the Motion of the Stomach and Inteſtines continues even after Death; and that even the Motion of the Heart itſelf may be recovered from its State of Reſt, by inflating or forcing any Liquor through the thoracic Duct, whereupon the Heart will immediately renew its Pulſation, and in a manner begin a ſecond Life: but then it muſt be obſerved, that this ſecond Pulſation holds but for a little time, and after a few Moments ceaſes, ſo as to be irrecoverable again by any Means.

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[9] We ſaid before, that the Brain is the Principle from whence the voluntary Motions are derived: but the Force which is derived from the Brain to the Muſcles can be communicated no other way than by the Nerves. Therefore if a Nerve is render'd paralytic, all the Muſcles which receive Branches and moving Force from that Nerve, will be neceſſarily relaxed, or render'd paralytic likewiſe. If thoſe five Nerves ariſing from the Neck, from whence all the Nerves of the upper Limbs are derived, be either compreſſed, eroded, or cut aſunder, all the Senſe of Motion in the upper Limbs will then periſh. If the crural Nerve be laid bare in the Groin of a living Dog, according to the Experiment of *Galen*, and then tied with a Ligature, all the Muſcles of the Leg and Thigh to which it is diſtributed become paralytic; and after turning the Animal looſe, when the Wound is ſewed up, he draws that Leg after him, as if it was no Part of his Body, but as if it hung by a String, being quite paralytic and immoveable. There is another elegant Experiment of *Bellini*, not indeed extant in his Books, but publiſhed in the *Italian* Journal, and in the *Acta Eruditorum Lipſienſia.* He took up the Nerve of the Diaphragm in a living Animal, and upon compreſſing it, that Muſcle which received Branches from this Nerve was render'd paralytic, namely, the Voice and Reſpiration were aboliſhed: but upon removing the Compreſſure from the Nerve, and moiſtening with a Spunge dipped in warm Water, the Senſe and Motion of the paralytic Muſcle gradually returned together with the Reſpiration. If a Perſon in Health ſleeps upon his Elbow, and compreſſes the large Nerve which runs along juſt within the Edge of the Elbow, the Senſe and Motion of the Fore-arm will be aboliſhed,

ed, and the Man upon waking will be ſurpriſed to find his Arm inſenſible and immoveable; but upon riſing up and ſetting the Arm at Liberty, the Parts recover their Senſe and Motion gradually, with an uneaſy tremulous Senſation being felt at the ſame time. From theſe Experiments I think it is ſufficiently evident, that the Principle or immediate Cauſe of Motion in the Muſcles does not reſide in the Fabric of the ſolid Parts, but in the Force of the Humours derived into them.

10 An Obſtruction in the Brain by Compreſſure, or otherwiſe, deſtroys the voluntary Motions; becauſe the Nerves, which are the Authors of thoſe Motions, are derived from the Brain. But the ſpinal Marrow ſends Branches only to the lower Parts of the Body; and therefore an Impediment or Injury in the ſpinal Marrow will only injure thoſe Parts which receive Nerves from the ſpinal Medulla beneath the Impediment. I ſaw a Goldſmith who had a Fracture in the Vertebræ of the Loins at the Os ſacrum: and here there was a Palſy of all the Parts below the Injury; the Semen, Urine, and Fæces of the Inteſtines came away involuntary, and without the Knowledge of the Patient. But whatever Parts are ſeated above the Injury in the ſpinal Medulla continue in their ſound and natural State, becauſe their Nerves are derived from that Part of the ſpinal Medulla to which no Injury has extended. There was a certain Vintner of *Leyden*, who was by Nation a *Walloon*, a very jocoſe Man, who by falling from the Ladder of a Mill, while it was turning round by the Wind, fractured the Vertebræ of his Neck; whereupon the Phyſician being called, adviſed them to carry him home, for he had not above an Hour to live: but yet even in the midſt of ſo much Danger, the ridiculous Fellow could not forbear

bear jeſting, and ſaid, That he had nothing more to complain of than that all his Limbs had deſerted him, like as unfaithful Soldiers deſert their Sovereign. He could breathe, think, and will freely; but then his Arms and Legs remained ſtiff and immoveable, without regarding the Influence of his Will: for the Nerves of the eighth Pair, with the Intercoſtal and ninth Pair remained free, ſo that the Heart, Lungs, Stomach, Viſcera, and Organs of Speech had their proper and free Motions. But he had no long time to jeſt; for ſoon after he grew ſtupid, and at length apoplectic, expiring in a deep Sleep, namely, becauſe the extravaſated Blood, which compreſſed the ſpinal Medulla aſcended into the fourth Ventricle, where by compreſſing the Cerebellum it put a Period to Life.

[11] If the axillary or any other Artery be tied in a living Dog without injuring the Nerve, both the Senſe and Motion of the Muſcles periſh in the ſame manner as if the Ligature had been made upon the Nerve itſelf. This Experiment was firſt made by *Swammerdam*, and was afterwards repeated and confirmed by many Experiments in *Tuſcany* by *Steno.*

[12] Whether it be a Muſcle which governs ſome Limb, as in the Biceps of the Arm; or whether it terminates or circumſcribes a Cavity, which is cloſed with an Orifice to which Action the Sphincters belong; or whether they belong to that Claſs ſerving to propel the Humours through the Veſſels, of which the Principal is the Heart.

[13] The Tendon, in Fact, becomes a ſmall matter longer by the Force of it Contraction, which tends towards the Center of the Muſcle: but this Elongation of the Tendon is too inconſiderable to deſerve the leaſt Notice.

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[14] The voluntary Muſcles, as well as the involuntary, are equally contracted or ſhortened as well as diſtended throughout every Point of their fleſhy Subſtance, while they continue in Action. Any Perſon has it in his Power to try this Experiment upon himſelf; for if he bites any thing hard, or ſhuts his Jaws cloſe, and at the ſame time applies one Hand to his Cheek, while the Fingers of the other Hand are introduced into the Mouth to feel the Maſſeter on the other Side, he will perceive it become harder and more diſtended in the Action, while he endeavours to elevate the lower Jaw, and preſs it ſtrongly againſt the upper. In general, all the Muſcles of the Body become hard and turgid only by the Influence of the Mind. I have ſeen ſome Poſture-Maſters who in public Shews have reſembled dead Bodies, in order to which they contracted all their Muſcles in ſuch a manner, as to render every Part ſtiff and immoveable, ſo as to be eaſily carried and treated as a Carcaſs by their Companions. That kind of Spaſm or Contraction of a Muſcle, which is called the Cramp, renders the Muſcle ſo hard that it feels like Iron. If you open the Thorax of a living Dog, and make an Inciſion in the Pericardium, you will perceive in what Manner the Heart contracts within its Capſule, and it will appear pale, bloodleſs, and turgid or ſwelled. If you obſerve the Motion of a Muſcle in an Animal after the Skin has been taken off, you will ſee that at every time of the muſcular Contraction, it will become turgid and ſwelled; and therefore the ſame Cauſe which produces the Motion of the Muſcle, does alſo at the ſame time render it tumid and hard. But if this Hardneſs and Diſtention of the Muſcle be too great, the Muſcle is thereby ſo much injured as to become paralytic, and frequently to produce Convulſions.

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[15] There is not any Part in the whole Body but what is capable of ſome Motion: Geometricians obſerve, that all the Actions are in an inverſed Ratio to the Reſiſtances; and therefore the Effect produced by the Motion or Contraction of a Muſcle is in proportion to the Reſiſtances of the Parts into which the two Ends of the Muſcle are inſerted. If the upper Ribs give the Reſiſtance of a hundred to the Action of the ſerratus anticus Muſcle, and the Scapula gives the Reſiſtance of one, while the Muſcle contracts itſelf each way both from the right and left, the Scapula will then be drawn a hundred Parts of the Space towards the Ribs, while the Ribs are drawn one Part towards the Scapula. But when the Ratio of the Motion of one Part is ſo very ſmall with reſpect to the Motion of the other, that of the leaſt is ſcarce obſervable, and is therefore uſually eſteemed the fixed Point. But if the fixed Point to which the one End of the Muſcle is faſtened has an infinite Reſiſtance with reſpect to the other, it will then remain immoveable, and the other Point only will approach towards it. But if both Ends of the Muſcle meet with the ſame Reſiſtance, then they both paſs through equal Diſtances or Spaces towards their middle.

[16] The lower Jaw of a Perſon in Health, who is neither fooliſh, deſirous of hearkening to ſomething, nor paralytic, is always ſhut or drawn up: but in the ſtrongeſt Perſon while ſleeping, it is relaxed or let down by an Elongation of theſe Muſcles by which it was before elevated. If you touch the maſſeter Muſcle with your Finger, you will not only perceive it ſwell and grow hard during the time of biting, but you will alſo perceive it relax or elongate alternately; for it is abſolutely neceſſary for a Muſcle to ſwell when it is ſhortened, by adding that to its Breadth which is diminiſhed from its Length.

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[16]* The Heart of a Frog appears evidently white and hard at the time of Contraction, and at the time of Dilatation the Heart appears red and flaccid. Therefore in the Contraction of a Muſcle its Blood is diſcharged. But this Appearance cannot be well obſerved in all Muſcles, becauſe the Fat obſcures their Alteration.

[16]** In the moſt exquiſite Statues of *Hercules*, preſſing *Laomedon* againſt his Breaſt, the deltoide and pectoral Muſcles are repreſented protuberant almoſt like Globes, while their antagoniſt Muſcles appear ſoft and flaccid. And this is the principal Art of Statuary, namely, to make all thoſe Muſcles ſtrong which are concerned in giving that Poſture to the Body which the Figure or Gladiator repreſents, by fixing the Riſings and Excavations in their proper Places. Whenever the antagoniſt Muſcle is at reſt, it is always relaxed; but when a Muſcle is contracted, it muſt neceſſarily gain as much in Thickneſs as it loſes in Length.

[17] We ſaid before that every tenſe Fibre in the Body is capable of contracting itſelf into a ſmaller Length; but the Power or Force of any Muſcle, as for Inſtance, any of the Flexors is eſtimated by the Acceſs of the Powers, by which it overcomes the Reſiſtances which oppoſe its Contraction: and therefore it manifeſtly follows, that if you relax a flexor Muſcle which was before in Action, the natural Force of the Extenſor, which was before overcome, will reſtore the Equilibrium, and recover the natural Poſture of the Part, in which Action the Muſcle is oppoſed on all Sides from being ſhortened, while the Extenſor recovers its Shortneſs, and the Flexor which was contracted recovers its former Length. Both the Flexor and Extenſor are now in the leaſt State of Violence, but yet they continue in ſome degree of Extenſion or Violence, ſince neither

of

of the Antagoniſts permit the other to be ſo much ſhortened as it would if left to itſelf; but this Violence being the ſame in all the Muſcles of the Body, is from the Equality or Juſtneſs of its Proportion render'd inſenſible to the Mind. The Arm of a Perſon hanging out of Bed, ſeems to have its Muſcles at Reſt; but yet they are not quieſcent, but ſupport each other in Equilibrio, and manifeſt their Action as ſoon as ever the Equilibrium is removed. In a Pair of Scales which have each a thouſand Weight, there is no Motion follows, though the Tendency is extremely great. Wreſtlers, who keep their Limbs ſtiff and ſuſpended, ſeem to exert no Force, even when they labour with all their Strength to ſupport themſelves; but that they do labour, may be known from the Artifice by which the one overcomes his Antagoniſt, while the other endeavours to turn himſelf ſo as to fall uppermoſt. But it is not always neceſſary for one Muſcle to be antagonized by the other, for that may be done by the Weight of the Part to be moved; as, for Inſtance, the lower Jaw with reſpect to its Elevators, or the Elaſticity of the Part, by which it recovers its natural State, unleſs altered by the Muſcle, as in the Antagonization of the intercoſtal Muſcles, or even the Weight of the ambient Parts themſelves, *&c.*

[18] The Back or Spina Dorſi is held direct, with no ſmall Force, by the Aſſiſtance of many and ſtrong Muſcles, which are called the Extenſors of the Back and Loins. Theſe Extenſors are antagonized on the Forepart of the Body by Flexors, which in moſt Parts of the Body are ſtronger than the Extenſors, ſo as generally to cauſe the Articulations to be a little inflected, and moderate the Extenſion within certain Bounds. Suppoſe now all the flexor Muſcles to be ſuddenly relaxed,

while the Force of the Extenſors remains as before, an Opiſthotonus, as it is called by the Ancients, will certainly follow, not becauſe the Power of the extenſor Muſcles is increaſed, but becauſe the Reſiſtance is removed which was made by the Flexors. It is not therefore neceſſary, as many have falſly imagined, for the Force of the Muſcles to be increaſed in order to produce Convulſions; for it is ſufficient only to render the Forces of the Muſcles unequal among themſelves. Hence therefore if any Part of the Brain is injured, ſo as to render the Muſcles paralytic, which derive their Nerves from that Part; in that Caſe the antagoniſt Muſcles will contract themſelves by their prevailing Force: and from hence follow Convulſions, even in extreme Weakneſs; and at the time of Death, Convulſions generally precede, which are uſually called Stretching out.

[19] Reaſon teaches us, that there muſt be ſome Interval of Time betwixt theſe Actions; but the Space is nothing with regard to our Obſervation, as it is inſenſible; even in the very Inſtant of Time that I incline to extend my Arm, ſo ſoon does it follow without the leaſt ſenſible Interval; and at the ſame time a Change is made in all the Extenſors; and if I alter my Inclination to bend it, it inſtantly follows. But theſe are ſimple Motions; yet are there others extremely complex, performed without the leaſt ſenſible Succeſſion of Time. We readily ſpeak a Word in a moment; whereas every Letter of that Word requires many different Motions of the Muſcles belonging to the Glottis, Fauces, Tongue, Cheeks and Lips. So many different Motions paſs through ſo many different Degrees thus readily, by the Influence of the Will, in an Inſtant of Time; ſo ſhort, that it cannot be meaſured by any Inſtrument.

[20] This Experiment was formerly tried by *Wepfer* and *Peyerus*, who injected warm Water into the thoracic Duct, which excited a vital Motion in the Heart, but ſomewhat weaker than in Life. The Experiment has been ſince tried by *Swammerdam*, at *Paris*, and in *Helvetia*. *Peyerus* injected the Arteries with warm Water in a Dog killed three Hours before, whereupon the Muſcles were ſuddenly contracted. *Cowper* obſerved the like Phænomenon in ſeveral Muſcles: he injected, for Inſtance, warm Water into the crural Artery of a dead Dog, and immediately various Motions of theſe Muſcles followed, which one would expect to receive their Blood from the ſame Artery.

[21] This is one of the more difficult Experiments; but yet we ſee manifeſtly in the Heart that its Bulk is not much diminiſhed, even when both its Cavities are emptied, and the Sides brought towards each other. When I move my Forefinger from the Wriſt towards the Thumb, I then eaſily perceive a Swelling of the Muſcle betwixt the two Fingers; and by applying the Fingers externally to the Maſſeter, with three Fingers internally within the Mouth, comprehending the Muſcle betwixt, moving the lower Jaw at the ſame time, or biting with a conſiderable Force, the Muſcle will be then perceived to ſwell both internally and externally, and will repel the Fingers with a conſiderable Force, when at the ſame time the Muſcle is limited in its Contraction by the meeting of the Teeth in the two Jaws; from whence we may conclude, that if the Maſſeter is not ſhortened at the time of biting, notwithſtanding it is ſwelled, its Bulk muſt be then increaſed. Another Experiment has been tried by *Borelli:* he ordered a Rope-dancer to lay his Body flat upon the Rope ſo as to find an Equilibrium, and then

to endeavour to move one half of the Body, while the other was at Reſt; but the Trial did not ſucceed, for whenever the Rope-dancer endeavoured to move the right Side of his Body, he could not prevent the Left from falling, unleſs he exerted a Motion on that Side like the former. *Borelli* then ordered a Man to ſit down in a Bath, and to keep his Body quiet, and after that on a ſudden to move all his Limbs with a conſiderable Force, and yet the Water maintained the ſame Height in both Caſes; ſo that this laſt Experiment was equally uſeleſs, ſince there was as much derived from the other Parts of his Body, as occaſioned the Turgeſcence or Swelling of the Muſcles. *Gliſſon* has left us another Experiment, which ſeems to demonſtrate, on the contrary, that the Muſcles increaſe their Bulk at the time of Contraction. He placed a large and tall Glaſs full of Water, ſo ſecurely that it could not move any way, and then inſerting his naked Arm at Reſt, and in a manner as if it was paralytic, he accurately obſerved to what Height the Water aſcended; after which endeavouring to contract all the Muſcles, he ſtrictly obſerved whether the Water which filled the Veſſel made any Aſcent or Deſcent; and he found that at the firſt Inſtant it deſcended a little, afterwards ſtood at the ſame Height, and upon a violent Contraction of the Muſcles rather aſcended; namely, that in the firſt Inſtant of time the Muſcle diminiſhed by expelling the Blood, but afterwards increaſed in Bulk by the Reception of Matter from the Nerves. If we only ſuppoſe the Water to have deſcended, and at the ſame time conſider the great Force with which the arterial and venal Fluids are preſſed out of the Muſcle in its Contraction, when at the ſame time the Muſcle itſelf either increaſes in Bulk, or at leaſt receives no ſenſible Diminution, we may conclude for certain, that there muſt be an Acceſſion of ſome Fluid, which enters and tumifies the Muſcle with a moving Force. And that this is a true Deduction, is demonſtrated by the Experiment of all the Muſcles ſwelling at the Endeavour to move, even though the Motion itſelf does not follow, nor the Muſcles become ſhorter. At leaſt this Experiment of *Gliſſon* demonſtrates, that the Motion of the Muſcles is not performed by any Effervеſcence, ſince from thence would neceſſarily follow a Tumor ſufficient to raiſe the Water. It even gives me ſome Uneaſineſs to find *Borelli* and *Bellini* aſſigning this Cauſe to muſcular Motion, who were ſuch good Judges in other reſpects.

[22] This is another and very remarkable Experiment of *Gliſſon*, who obſerved that the deltoide Muſcle in raiſing the Arm became viſibly ſhorter and more tumified, while its Tendon elongated, and therefore that very Muſcle ſeemed to increaſe its Bulk at the time of Contraction. At another time he ordered the ſame Man to depreſs the Arm with all his Might, while at the ſame time two ſtrong Men endeavoured to lift his Arm up, ſo as to overcome the Reſiſtance of the ſingle Man; the Event was, that the deltoide Muſcle became ſhorter even though it was at Reſt, and ſwelled conſiderably, while the Arm was elevated contrary to the Reſiſtance of the ſingle Man. This Experiment may be made in ſome of the interoſſei Muſcles without the Aſſiſtance of another. Cauſe any Finger to be drawn outward, and at the ſame time with the other Hand thruſt the Finger more forcibly inward, and you will then perceive the interoſſeous Muſcle ſwell in the ſame manner as is uſual in muſcular Motion. The Reaſon of theſe Phænomena is as follows: A Muſcle while relaxed and elongated receives ſo much more Blood, as its

Reſiſtance is leſs than before; and therefore the deltoide Muſcle in the firſt Experiment received more Juices, ſince it ſpontaneouſly ſwelled by the Approximation of its Fibres; but when relaxed, the Blood and Humours will find a more ready Paſſage, and flow in a greater Quantity, as being excluded by the Straining or Contraction of the antagoniſt Muſcles; and therefore this Turgeſcence of the Muſcle is rather ſanguine than nervous, nor does that Hardneſs follow in it, which is obſerved in the voluntary Motion of a Muſcle.

[23] This is a Propoſition ſo evident, that it admits of no manner of doubt; for if the Condition of a Muſcle is not altered by the Mind or Will, in that Caſe the Spirits or Juice of the Nerves will flow equally and conſtantly from the Brain into all the Muſcles alike; nor can any Change be made in the Muſcles by the Heart, which equally propels its Blood by the Arteries through every Part, as we experience when all the involuntary Motions continue, while the reſt are aboliſhed in Sleep. In Sleep therefore none of the voluntary Muſcles will prevail, or be brought into Action, but only the vital Organs will labour, as the Heart, Inteſtines, Stomach, and reſpirative Organs.

[24] There is no room to doubt, but that there are ſeveral voluntary Muſcles in the Body which operate only from Cuſtom by the Influence of the Mind, of which by continued Uſe we are inſenſible; which Muſcles taking their firſt Action from the Command of the Will, do nevertheleſs afterwards continue to operate in a manner as if it was ſpontaneouſly. We often walk at the ſame time that we are thinking or talking upon divers Affairs; and when we firſt wake out of our Sleep in a Morning, we ſit up in the Bed, and throw our Muſcles into that Poſture to which they have been

accuſtomed through the whole Courſe of Life, without giving them any ſenſible Command by the Will.

§. 402. From duly conſidering the ſeveral *Phænomena*[1] before-mentioned (§. 401.), the Properties of the latent *Cauſe*[2] of Motion in the Muſcles will plainly appear: ſuch as,

1. That it is a Power capable of being preſent and *abſent*[3] in the Muſcle.

2. And conſequently that it can *enter into*[4] and go out of the Muſcle.

3. That it is derived into the Muſcle from ſome other Part without, and again *returns*[5] to ſome other Part without the Muſcle.

4. That it enters and returns in this manner in a Moment, and by the *Influence*[6] of the Will.

5. And that in the very Inſtant of time when a Muſcle contracts, all the Fibres thereof are preſſed or urged from within *outwards*,[7] towards every Point of the Surface of the Muſcle, even in oppoſite Directions.

6. That therefore it muſt be equally diſtributed at one and the ſame time throughout all the Fleſh of the Muſcle.

7. And that it ſo *dilates*[8], fills and alters the Membranes of the Fibres, as to reduce them from an *oblong*[9] to a rounder Figure, increaſing their ſmaller Diameter, and diminiſhing their larger, ſo as to bring the Tendons nearer to each other.

8. And that this Cauſe muſt of Neceſſity proceed from the *Brain* [10], Cerebellum, and Origin of the Nerves, and that it is able to overcome the Reſiſtances by which it is ſtrongly oppoſed in the Muſcles.

9. And laſtly, that we muſt therefore conclude this Cauſe can be no other than a very thin *fluid* [11] *Body* [12], very eaſily or *quickly* [13] moved, and that it muſt be *forcibly* [14] thruſt into or applied to the Muſcle.

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[1] If a Man was to be born at once Adult with his Senſes perfect, he would be ſurpriſed at the Perception of the Motions and Noiſes of the ſeveral Limbs and Parts of his Body, while they are in Action: but theſe we do not perceive, much leſs are we ſurpriſed at them, merely from Cuſtom or Uſe, notwithſtanding we hear and feel them perpetually; for it is a Property of the human Body to raiſe its Perceptions only from thoſe things to which it is leſs accuſtomed.

[2] There muſt of neceſſity be a Cauſe which renders a Muſcle in Motion different from one at Reſt; and as this Cauſe is unknown to us by not falling immediately under our Senſes, it is to be therefore traced and diſcovered by the Appearances which it affords, taking care as we proceed to avoid mixing Falacy with Truth. But what we have hitherto ſaid, appears to be no more than what is ſupported by faithful Experiments; and therefore the Cauſe itſelf ought to be ſuch as will correſpond and agree with the Phænomena mentioned in the fourteen Numbers of the preceding Section (§. 401.)

[3] But ſince there is no Muſcle in the Body but what is capable of Reſt and Action alternately,

therefore the Cauſe of the Action muſt be capable of being preſent in, and abſent from the Muſcle; that is, it cannot proceed from any ſpontaneous Action in the Muſcle itſelf; for if it was ſo, the Muſcle would perpetually remain contracted.

[4] Nor can this Cauſe reſide in the Muſcle itſelf; for if it dwelt there, it would perpetually act or produce its Effect uniformly alike, ſo that the ſame Muſcle would be always either conſtantly relaxed or contracted: and beſides this, it muſt not only enter from without into the Muſcle, but it muſt alſo be equally diſtributed, and penetrate into every one of the ſmalleſt Fibres, ſo as to diſtend or fill them out.

[5] When the Harp is ſtruck by the lumbrical Muſcles which move the Fingers, the moving Cauſe or Power muſt neceſſarily paſs ſwiftly into and from each Muſcle, ſo as to deſert one and contract the other; and therefore this Cauſe muſt truly exiſt without, and be capable of paſſing from the Muſcle by ſome Courſe after it has enter'd into it.

[6] I no ſooner incline to bend my Leg, but it is done with an incredible Swiftneſs, inſomuch that it frequently exceeds, or rather eſcapes being meaſured by the leaſt known Parts of Time. The Ears of muſical Gentlemen are very learned, and divide Time firſt into the *Battuta quadrata*, or the largeſt Touch, which is the fifteenth Part of a Minute; and this Portion of Time they again diſtinguiſh into four equal Parts, which four they ſubdivide into ſixteen Parts; ſo that at length four Seconds of a Minute are divided into ſixty-four Parts, and the whole Minute of Time into 960 Parts. But ſkilful Muſicians know how to run through the ſixty-four Parts of the fifteenth Portion of a Minute ſo exactly, as to diſtinguiſh each Particle of Time.

This Inſtance may therefore ſuffice as a Specimen of the ſudden or ſwift Action and Relaxation of a Muſcle; but if Muſicians can thus minutely divide Time, the Action of the Muſcles themſelves muſt be much ſwifter than any mechanical Obſervation of the Muſician poſſibly can, as we obſerved before in the Muſcles of Speech.

[7] The maſſeter Muſcle in the Act of biting ſwells uniformly on all Sides, and repels the Fingers betwixt which it is comprehended; and therefore the Force by which the Muſcle is indurated, muſt be diffuſed at one and the ſame time through every individual Fibre, directly in the ſame manner, as when a Bladder dilates uniformly when it is inflated by a Pipe; ſo that no one Part of the Muſcle remains relaxed, while another is contracted; but all the Fibres at once become turgid, which were before ſoft and lax. Beſides this, in order for a Muſcle to repel the Fingers from its Surface, it is neceſſary for the reſiſting Cauſe to operate with a Force continued from the Center of Gravity at one Inſtant towards every Point of the Surface of the Muſcle, in the ſame manner as if a Thread faſtened to a Center was to be moved all round from the Center to the Circumference at one Inſtant. When the Muſcle is again relaxed, it grows ſoft, and yields to the Finger in the ſame manner as if every Part was drawn from the Circumference to the Center by an infinite Number of ſmall Threads.

[8] A Muſcle is compoſed of mere hollow Tubes or Threads; but all the Veſſels in the Body grow hard when filled with Humours, and feel ſoft again when they are emptied. An empty Bladder may be thrown at a Perſon without doing any Injury; but if the ſame Bladder is filled with thirty Pounds of Water or Mercury, it may kill the ſtrongeſt

Man: and therefore in order for the Muſcle to become hard and turgid, it is neceſſary for all its Veſſels, even the moſt minute, which are much leſs than thoſe of *Lewenhoec* and *Ruyſch*, to become exquiſitely turgid. But if this Repletion of the ſmalleſt Veſſels is the Cauſe of the Hardneſs in a Muſcle, and the Muſcle is found to be indurated in every Part at the ſame time, it follows that the corporeal Cauſe of the Motion muſt be diffuſed on all Sides from the Center towards every Point of the Circumference.

[9] Since the Fibres are filled by the Middle of their Centers, and their Centers are by that Means dilated, their Extremities muſt neceſſarily approach nearer each other, and each extended Fibre or Vaſcule muſt become ſhorter. *Bernoulli* has demonſtrated, that a circular Fibre which is perfectly flexible being given, and a Liquor is impelled into the Cavity of the Fibre, it will acquire no other Figure than that of a Sphere; for ſince every Point is equally preſſed by the Force of the diſtending Liquor, it can aſſume no other Figure than that of a Sphere; and if the Quantity of Liquor is ſufficient, it will continue to be filled till it actually becomes a Sphere; but there its Repletion muſt ſtop, becauſe a Globe is of all Figures that have equal Sides, the moſt capacious. Since therefore the Length of a Muſcle in Action is diminiſhed, its leſs Diameter or Thickneſs muſt be increaſed of neceſſity, and the reverſe.

[10] And that this Cauſe muſt be derived from the Brain is evident; becauſe while that and its Productions the Nerves remain entire, and in their natural State, the Muſcles are all capable of their Motions, but are deprived of their Action ſo ſoon as the Efficacy of the Brain and Nerves is aboliſhed.

But

[11] But that it muſt be a very ſubtle Fluid, is evident from the infinite Number and Minuteneſs of the Veſſels; nor yet would the Muſcle be ſwelled by ſuch a Fluid, unleſs it was to be impelled by ſome moving Cauſe. But we know not of any Fluid in the human Body more ſubtle than that which is derived from the Brain through the Nerves; ſince that Fluid is generated from the thinneſt Parts of the Blood, ſo prepared in the Brain, as that the moſt ſubtle Parts only of it can enter into the Medulla and Nerves.

[12] It is a common Property of every Body to be hard, or afford a Reſiſtance to an external Impulſe; and this Property of Matter, which has been infuſed into it by the wiſe Creator, is known under the Denomination of Impenetrability or Reſiſtance, which is inſeparable from any Body. But a Muſcle reſiſts on all Sides when its moving Cauſe is applied, and therefore the Cauſe of its Motion muſt be coporeal.

[13] The *Italian* Singers, whoſe Voices are bought at a high Price, know how to yield diſtinct Tones or Notes with ſo much Celerity, as to run through ſixty-four Shakes within the Space of one *Battuta quadrata*, or four Seconds of Time. But the Cauſe of ſo ſwift a Variation is only a Dilatation and Contraction of the Glottis, ſo as to be wider at one time than at another: and this Variation again ariſes from the Action of the Muſcles proper to the Larynx, and theſe again derive their Cauſe from the Brain, which is placed at more than a ſmall Diſtance from the Larynx. It is therefore evident that the Muſcles move with a very great Celerity.

[14] The Force of the Muſcles appears to be exceeding great. When the deltoide Muſcle raiſes the Arm at full Length free from any additional

Weight, it exerts a Force, eſtimated equal to five thouſand Pound, by collecting together all the Reſiſtances. But there are ſome Men who can write Letters upon a Wall with their Hand, even though there are fifty Pounds in Weight appended; whence the Force of the Muſcles will appear to be very great and ſurpriſing. —— Hitherto we have only propoſed what is ſtrictly agreeable to Reaſon and Experiment, and which muſt be allowed for Truth without any manner of Controverſy, as being naked Experiments and Phænomena themſelves; but it now remains for us to proceed further by the Aſſiſtance of reaſoning.

§. 403. Now the Qualifications required in the Cauſe (§. 402.) are all found in the *nervous* [1] Liquor, and in no *other* [2] Humour; and therefore that Liquor is to be acknowledged for the true *Cauſe*; nor is it difficult to underſtand its Manner of Action.

[1] The Liquor or Juice of the Nerves, which paſſes out from the cortical Subſtance through the medullary Tubuli, is the moſt fluid (§. 275.), the moſt ſolid, and like the Albumen which has been moſt highly attenuated (§. 276, 277.), is not the leaſt acrid (§. 278.), upon which the Action of every Nerve depends (§. 284, 286.); but the Action of the Muſcles reſults either entirely from the Nerves, or at leaſt more from them, than from any other Cauſe (§. 401. N°. 4.): and therefore the nervous Juice is every way adapted to be the Cauſe of Motion in a Muſcle.

[2] This Cauſe cannot reſide either in the arterial or venal Fluids, ſince they are equally made and diſtributed every Moment through all Parts of the

Body; nor can it reſide in the Loculi or Cells, in which there is not any moving Power.

3 In Phyſics, the Demonſtration of the Cauſe of any Appearance, is the demonſtrating the Co-exiſtence or immediate Connection betwixt the Cauſe and its Effect, or Appearance: as if the Cauſe of the Being A, reſides in that of B; then the Entity B being ſuppoſed, that of A will alſo neceſſarily ſubſiſt; and as B is either increaſed, diminiſhed, or totally aboliſhed, ſo conſequently will that of A: and the reverſe, that is, as the Effect A appears either increaſed, diminiſhed, or removed, the Cauſe B muſt be ſo likewiſe. A Perſon who ſees Gold melt in the Fire will doubtleſs readily attribute that Effect to the Fire, and laugh at any Perſon who ſhould contradict; but in this ſtrict Way of reaſoning we ſhall certainly find, that the Cauſe of Motion in the Muſcles is contained in the Nerves.

§. 404. But from *whatever* [1] Cauſe we ſuppoſe the Spirits to flow *more ſwiftly* [2] from their Origin into one Nerve than into another, a greater Quantity of them will flow into the Fibre open to that Nerve; and this Fibre will be therefore more *dilated* 3, at that time loſing its Elaſticity, will yield to the Action of the Cauſe, and produce the Effects mentioned (§. 402. N°. 7.); which Effects will increaſe, as the Cauſe continues or is increaſed, and therefore it will be tumefied throughout in the ſhorteſt Inſtant of Time, remaining contracted as long as it is thereto determined by the Continuance of the ſame Cauſe; and while this happens in the Fibrils, which are infinitely ſmall and numerous as to Senſe, the whole Effects or Appearances of them will be ſummed up and exhibited by the Muſcle itſelf acting in the ſame manner.

[1] If you enquire after the Cauſe which produces this greater Celerity of the nervous Juice at pleaſure, I muſt openly confeſs my Ignorance of it. The only Writer that has left us any thing tolerable upon the Subject is Dr. *Ridley* in his Treatiſe of the Brain, *chap.* 12.

[2] A Reſt or Inactivity of the human Body follows, when the nervous Juice is equally diſtributed from its common Fountain throughout all the Muſcles of the Body; for at that time the contractile Power of the Muſcles is ſuſtained by each other. If now in ſuch a State of the Body the Nerve of the deltoide Muſcle propels its contained Juice with twice the Celerity with which it paſſes through the Nerves of the other Muſcles, in that Caſe the deltoide Muſcle will receive twice as much Spirits in a given time, as is received by any other Muſcle of the ſame Size, by which not only the Trunk of the Nerve will be diſtended, but as its Branches and the Fibres open to them reſiſt the leaſt, they will be alſo filled. And this Redundancy of the Spirits will be continually augmenting. For in the ſame manner as from the Doctrine of *Galileo*, the Effect of Gravity continually increaſes, while the firſt remains and continues to act; ſo in this Inſtance the nervous Juice will be multiplied by a continual Acceſſion, ſo as to become immenſe in the ſhorteſt Space of Time, that is, in the Second of a Minute. You would perhaps ſay that this is a Propoſition rather aſſumed than demonſtrated, namely, that the nervous Juice is more ſtrongly impelled into one Muſcle

than into the reſt; but this is an Objection to which all Hypotheſes lie open in whatever manner muſcular Motion is ſuppoſed to be performed, whether from an Influx, Mechaniſm, or any other Cauſe. Certain it is that the nervous Juice muſt neceſſarily move, and that its Motion muſt continue from its Origin to produce this Change in the Muſcles.

[3] The Expanſion of any flexible Veſſel is in proportion directly to the Quantity of the impelled Liquor, and inverſly as the Reſiſtance of its Sides. Now in the Veſſels of the Muſcles the Reſiſtance of their Sides remains the ſame, but the Quantity of affluent Juices is increaſed, and therefore the Veſſels will be dilated. *Bernoulli* demonſtrates, that every Cylinder filled in its Center will ſwell in the Middle, while the two Ends are brought nearer to each other, by which the Length of the Cylinder is ſhortened, till at length if the Veſſel does not break, and the filling Force does not terminate, the Veſſel will become perfectly ſpherical. But in this Caſe he adds, that the Cylinder will never be more than one third Part of its Length ſhorter; and therefore no Muſcle can become ſhorter than one third Part of its Length. So long as this ſwifter Motion of the Juices into the Muſcle remains, ſo long will it be harder; and upon removing the increaſed Motion or Afflux, it will be reduced to an Equilibrium with the reſt of the Muſcles.

§. 405. It therefore follows, that this Celerity (§. 404.) being increaſed in one Nerve, the reſt will be ſo much the *leſs* [1] urged; and therefore theſe being relaxed, the Acceſs of the Force in the contracted Muſcle will act ſo much the ſtronger.

[1] The Quantity of Spirits in a human Body is not increaſed by muſcular Motion, nor does the Will generate the Cauſe of their Motion, but only determinates or directs the ſame. But the Spirits are retained without Loſs, when the Body is at Reſt, and all the Muſcles held in Equilibrio: but when an increaſed Quantity of Spirits is determined to any Muſcle, in that Caſe ſo much the leſs is ſent to the other Muſcles, as there is more determined to the Muſcle in Action. If there are a thouſand ſmall Muſcles, and one of them is filled by the Will with a double Quantity of the nervous Juice, then every one of the other Muſcles will be deprived of a thouſandth Part of the Juice which they would otherwiſe have had; and if the one Muſcle in Action is expanded to twice its uſual Thickneſs, all the other Muſcles will be contracted one thouſandth Part.

§. 406. From theſe two Cauſes (§. 404, 405.) all the turgid Fibres of a Muſcle will contract the *Intervals* [1], or interpoſed Spaces which lie betwixt them, together with the Blood-veſſels which are there diſtributed, and with a conſiderable Force; from hence the Veins will be emptied, the Arteries *compreſſed* [2], and the groſſer or red Parts of the Blood repelled, while the more *ſubtle* [3] Humours are by the Force of the Heart urged on into the ſmalleſt Veſſels and Fibres: and thus the Blood being expelled, while the whole Body of the Muſcle is ſupplied by the Nerves and Arteries with the more ſubtle Humours, we perceive that the Action follows, and every Condition required by the moving Cauſe is ſatisfied; for that Part of the Body will be moved or drawn to which the Tendon of the contracted Muſcle is faſtened, provided it makes ever ſo little leſs Reſiſtance than the Force of the Muſcle which acts upon it.

[1] A Muſcle is compoſed of ſmall fleſhy Fibres, which are in a manner ſo many Nerves expanded into impervious Cylinders; and betwixt theſe Fibres are interpoſed the other Veſſels of all Kinds, ſanguiferous, ſerous, and lymphatic. Now when the Arteries, Veins, and nervous Fibres are filled with ſome equable Force, the Magnitude of their Arteries will be limited, and ſo will alſo the Thickneſs of the nervous Fibres. If the Fibres themſelves are increaſed in Bulk without any Alteration in the Veſſels, then of neceſſity there will be an Alteration in both; for ſuppoſe there are four Arteries and four Bundles of Nerves mixed together in one Faſciculus of muſcular Fibres, the Compreſſion of the Arteries will be limited or determined to a certain Degree: but now ſuppoſe the Nerve to be increaſed as large again, the Diameter of the Artery will neceſſarily be ſubduple, and therefore the Arteries and Veins interpoſed betwixt the Nerves will be compreſſed. Nor does it ſeem true, which is aſſumed by ſome Authors, namely, that the Veſſels of a Muſcle are totally emptied at the time of its Contraction. It may indeed be admitted with reſpect to the Veins, but the Arteries are continually filled and dilated by the Force of the Heart. Beſides, as much nervous Juice as any Muſcle acquires, ſo much is derived from the reſt of the Muſcles; and therefore the other Nerves of the Body will be leſs filled, and make a leſs Compreſſure upon the Arteries: there-

fore in all the other Parts of the Body there will be a leſs Reſiſtance to the Afflux of the arterial Humours; ſo that the Blood will paſs from the Arteries of the contracted Muſcle, into thoſe of the adjacent Muſcles which are relaxed. But the Veins will alſo propel their Blood in the ſame manner into the other adjacent Veins, when a Muſcle contracts; and thus the Quantity of the groſſer Humours will perpetually diminiſh or depart from the contracted Muſcle, ſo much the more in proportion as it remains longer in Action, and the harder, paler, ſtronger and ſhorter will it be; ſo likewiſe will it be paler and more bloodleſs, and ſo much the greater Acceſſion will be made of the Blood into the other Veſſels, as there is a larger Quantity of Spirits determined to the Muſcle. But all that Space which was before occupied by the expelled Blood, will be now filled by the Acceſſion of Spirits and more ſubtle Juices; whence it is that the Muſcle not only retains its Bulk, but maintains its Turgeſcence and Hardneſs, notwithſtanding it has been deprived of ſo great a Part of the groſſer Humours.

[2] I muſt own myſelf to have been formerly pleaſed with the Syſtem of *Tauvry*, namely, that the Nerve ſpending itſelf upon the Anaſtomoſes or ultimate Extremities of the ſanguiferous Arteries, acted as a Sphincter to contract them, and ſtop the free Paſſage of the Blood from them into the Veins, while at the ſame time the ſmalleſt Veſſels continued pervious beyond the Extremity of the Artery.

[3] Namely, the moſt ſubtle Humours of the ſmalleſt Arteries, which are like Nerves (§. 346, 402.) aſſiſting the Operation of the Nerves, which are changed into muſcular Fibres. Theſe Juices being more plentifully ſent into any Muſcle, make

up for the Loſs of the groſſer Humours, which are expelled from the Muſcle. There now remain ſome Difficulties to be removed, concerning the Motion of the Muſcles performed in this manner: ſuch as, 1. How it is poſſible for ſuch ſmall Tubes, agitated by ſuch an exceeding ſmall Quantity of Spirits, to generate ſuch powerful Motions, inſomuch that *Borelli* ſhould make the Power of the deltoide Muſcle only to be equal to five thouſand Pounds Weight. 2. Why ſo great a Force applied to ſuch tender Fibrils does not ſooner break them than raiſe the Weight. But to both theſe Queſtions Anſwers may be given from Hydraulics (§. 411.): for I have often raiſed eleven hundred Weight only by the Force of my Breath blown through a ſmall Tube, which is certainly one of the moſt ſimple of Machines.

§. 407. But this Cauſe (§. 404.) ceaſing, all the Parts are at once reſtored to a perfect Equilibrium with each other, as well by the Elaſticity of the Fibres, and the equable or counterpoiſing Force of the other Muſcles, as by the Reaction of the circumjacent Parts, which have been ſtretched beyond their Tone by the Contraction of the Muſcle itſelf. *Every* [1] Appearance and neceſſary Circumſtance therefore of this Motion (§. 401, *& ſeq.*) is thus ſatisfied by underſtanding the Fabric and Cauſe attending in the Muſcle itſelf, only by aſſuming or ſuppoſing a Power increaſing the Celerity of the Juice at the *Origin* [2] of the Nerves, which laſt is not to be reaſonably expected to be accounted for (§. 27. N° 10.)

[1] Thus I think we have accounted for all the Appearances before-mentioned (§. 402.), and that without aſſuming any thing but what is demonſtrated. If you object, that we aſſume or ſuppoſe that the Fibres of the Nerves and Muſcles are hollow; I anſwer, that we have before demonſtrated at large, that the Nerves are mere ſmall Tubes continued from the Arteries in the cortical Subſtance of the Encephalon (§. 289, & *ſeq.*)

[2] Whether from the Mind? Thus it ſeems to be without doubt: but that the Origin of the Celerity begins in the Brain itſelf is moſt certain; but then where, or in what Part of the Brain does it operate? This ſeems to be in the common Senſory, that is, in the Confines betwixt the ultimate and ſmalleſt Arteries, and the Beginning of the medullary Tubuli (ſee 574.) But what Action is it that the Mind exerts upon the Nerve? Certainly I know not, nor does any one Mortal beſides. Whether or no it conſtringes the Nerve, and by that means propels the nervous Juice more ſwiftly? Certainly there ſeems to be no other Way, by which that Juice can be propelled, than by a Preſſure at the Origin of the Nerves. But in whatever Way it acts, whether by propelling the Juice, or by dilating the Nerve, and deriving the Juice; the Difficulty in determining its immediate mechanical Action will always remain, that is, it will always remain to be accounted for, in what manner the Mind can act upon elaſtic Bodies which repel each other, ſo as to force them into the Nerves. We ſhall not in this Difficulty have recourſe to the Opinion of *Willis*, by ſuppoſing it to operate as if Oil is mixed with Spirit of Vitriol; or a fermentable Acid mixing with the alcaline Spirit of the Blood, according to the Theory of *Borelli.*

§. 408. The *incorporeal*[1] Faculty of *Galen* inflating the Muſcles will be here of no Service to us; no more will the Mixture of a *nitrous*[2] Spirit of the Nerve with the Oil of the Blood rarefied or kindled into an exploſive Power. Much leſs ſhall we be aſſiſted by the Mixture of an *acid* [3] Spirit of the Nerves with the alcaline Spirits of the Blood, nor yet by an Ebullition of *Æther* [4] with the arterial Humours, nor yet an Increaſe or Diminution of the Power of *Attraction* [5] betwixt the moſt minute Parts of the Solids and Fluids: for theſe are all repugnant to Senſe, the Fabric of the Organs, the Matter, Mixture and Proportion of the Humours, with the Continuance and Number of the Appearances obſervable in this Action. Nor have we the leaſt Occaſion to call in their Aſſiſtance.

[1] *Hippocrates* very wiſely diſtinguiſhed three Parts in the human Body, namely, the (τα εχομενα) contained, the (τα εχοντα) containing, and that (το ενορμȣν) which impels; by which laſt he underſtands the Will or Action of the Mind diſtinct from Nature, which he places in the other two, namely, in the Veſſels and their contained Humours. This Opinion is expreſſed by *Paracelſus* in other Words, when he ſays that he finds Veſſels, Humours and Imaginations in the human Body. *Galen* formerly propoſed an incorporeal Cauſe inflating the Muſcles, which he takes from the *Impetus faciens* of *Hippocrates*. Even at the preſent Time there are many eminent Phyſicians, who admit of no other Cauſe than the (το ενορμȣ͂ν) Impulſe of the

Will to move the Muſcles. I readily admit, that the Mind is the firſt Mover or Cauſe of Motion in the Muſcles; but then I place the Exerciſe of its Action only in the common Senſory: for in the Muſcles themſelves the moving Cauſe muſt be corporeal, which was not reſiding there before the Contraction of the Muſcle, as is evident from the Hardneſs and Reſiſtance perceptible in a Muſcle by the Touch, during the time of its Contraction. Even if the incorporeal Cauſes from whence the Origin of Motion in the Muſcles is derived, were uſeful to be underſtood and explained, yet it would make no Alteration in this Courſe of Changes, which are made by corporeal Cauſes in the Muſcle itſelf: and beſides this, the Impulſe of *Hippocrates* and *Galen*, which is immaterial, can never be conceived nor underſtood by us, ſince we are altogether ignorant of the Manner in which God has connected the Body and Mind.

[2] *Willis* obſerved, that well rectified Oil of Vitriol, or pure Spirit of Nitre, mixed ever ſo gently with Alcohol Vini, produced a ſudden Efferveſcence with ſo conſiderable a Force, as to break the Veſſels if they were not very open. From hence that Gentleman conjectured, that perhaps the animal Spirits might be of an acid Nature, but that the Blood abounded with oily Particles, and that from a Mixture of theſe two, an Exploſion aroſe like that from a Mixture of Oil and Acid, by which the Motion of a Muſcle might be produced. But here we may obſerve, that, 1. The Efficacy of the Mind is here equally required to determine the Mixture of an acid and oily Liquor more in one Muſcle than in another. 2. It does not ſufficiently appear, how the Mind could regulate or moderate ſuch an exploſive Force, ſo as to correſpond to any particular Weight in a geome-

trical Proportion. 3. This Sulphur of the Blood, and acid Nature of the Spirits, are the mere Produce of Imagination (§. 277, 167.) 4. Such an exploſive Force of Oil and Spirits would deſtroy the Fabric of the Muſcle itſelf.

[3] It gives me ſome Concern to find *Borelli* and *Bellini* ſhould admit theſe Hypotheſes, namely, that an Efferveſcence ſhould ariſe in a Moment betwixt an acid Spirit of the Nerves, and the alcaline Blood, in the ſame manner as if a Mixture of Spirit of Vitriol with an alcaline Salt in a Bladder, was to diſtend the muſcular Fibres, and contract the Muſcle itſelf. But we have before ſufficiently demonſtrated, (1.) That the Humours of a healthy Body neither contain any Acid nor alcaline Salts. 2. And that ſuppoſing ſuch Humours in the Body, there muſt be diſtinct Veſſels, ſome for the Acid and ſome for the Alcaline; when at the ſame time there are no ſuch Veſſels in the Body, as are capable of reſiſting the corroding Power either of Acids or Alcalies. (3.) Admitting there may be ſuch a Mixture in the Muſcles, it will not explain, why ſuch an Efferveſcence ſhould ceaſe in one Muſcle more than in another, without keeping them continually in Action, ſince the Afflux of the Humours into the Muſcles from the Heart and Brain is continual, though more copious at one time than at another.

[4] The Action of the Muſcles was formerly derived by *Carteſius* and *Bernoulli* from a ſubtle Æther; to which add Sir *Iſaac Newton.* Optics, *Quer.* 24.

[5] This Hypotheſis of Attraction is propoſed by *Keil*, namely, that there are ſome Parts in the Blood endowed with a peculiar Force, by which they attract and repel each other; and which are ſenſibly at Reſt, when they are mixed in a deter-

minate Proportion; but ſo ſoon as any one Sort of the Particles abound ſeparately in a Muſcle they repel each other with a conſiderable Force, in proportion to the Force with which they met or attracted each other; and this in the ſame manner as Air, each individual Particle of which is not elaſtic nor real Air, but two or more of them together repel each other, and form Air. But ſuppoſe we admit ſuch an Hypotheſis without any Demonſtration, what would it avail againſt the Objections and Difficulties that may be raiſed againſt it. For though that Part of the Blood which makes the Attraction receives a quicker Motion from the Brain, this will not explain how thoſe Parts only ſhould remain in the Muſcle which repel and extend its Fibres, while thoſe Parts recede which made the Attraction; nor do we obſerve any ſuch Particles which thus attract and repel each other in the Fluids of the human Body. Certain we are, that the Particles of the thick Blood itſelf, do by their Viſcidity ſtrongly attract each other; but it would be an inſuperable Difficulty to demonſtrate that it contains elaſtic Air, or Particles which repel each other: nor can it be of any Force to apply thoſe Properties to the Blood, which we obſerve in the Magnet, or in elaſtic Air, which are Bodies very different from the Blood itſelf. It would alſo be difficult by this Hypotheſis to explain by what Means theſe Attractions and Repulſions could be ſo ſuddenly produced and quieted by the Mind, or how they could be ſo conſtantly and regulary continued by alternate Separations and Conjunctions, or Attractions, during the Space of a whole Day, as we obſerve in the Huſbandman and thoſe who lead a laborious Life.—I propoſe theſe Opinions to ſhew that the Phænomena of muſcular Motion cannot be explained without the Aſſiſtance of a nervous Juice: and that the Syſtem which we have before propoſed is every way ſufficient, namely, that the muſcular Fibres have ſuch a Fabric, as reſembles a ſmall Pipe inſerted into a Bladder, much after the manner of the Air-bladders in Fiſh, which by a contractile Force can diſcharge the contained Air, and by relaxing can admit more Air at the Pleaſure of the Animal, according as it inclines to ſwim either towards the Surface or Bottom of the Water. Small Bladders of this Kind will ſwell ſuddenly if they are filled, and ſubſide again as ſuddenly when the filling Power is removed.

§. 409. But this equable Influx of nervous Fluid happening at once in all the Muſcles of the whole Body, cannot at the ſame time flow into the *Heart* [1] while contracted, but is collected in the Nerves thereof; ſo that this Muſcle being filled by the Auricles, Vena Cava, and pulmonary Vein, with Blood paſſing into its Ventricles, and into its Subſtance by the coronary Arteries, where at the ſame time its muſcular Fibres are filled by the Nerves; by theſe Cauſes the Heart is violently contracted in an Inſtant: but ſoon after the venal Blood, being in the mean time plentifully and forcibly brought into the Auricles and venous Sinus's by violently diſtending their Sides, it compreſſes the cardiac Nerves which lie near them; while at the ſame time thoſe cardiac Nerves which paſs into the Heart by the Side of the Aorta and pulmonary Artery, are alſo compreſſed by the Expanſion and Repletion of thoſe Veſſels; therefore the Heart becomes paralytic, and being relaxed is again filled; and by this means all the cardiac Nerves being ſet at liberty again, the Heart will be contracted, and in that manner will it continue to act and reſt alternately. But with reſpect to the ultimate Action of the Muſcles of *Reſpiration*[2] we ſhall ſpeak hereafter, at §. 601, *& ſeq.*

[1] The Heart alone moves all the Humours in the Body, together with the ſolid Parts, and likewiſe all the Muſcles; for if you do but take out the Heart, every Part ſoon loſes its Motion and dies, except the Inteſtines, which continue their vermicular Motion a conſiderable time after they have been taken out of the Body. It therefore now remains for us to examine how the Heart moves itſelf, ſince it is that which moves all the other Parts in the Body. There are three Cauſes which concur towards the Contraction of the Heart, namely, 1. The venal Blood which the Heart receives into its Ventricles out of the Sinus's and Auricles. 2. The arterial Blood, which being forced back by the Contraction of the Aorta, is impelled into the coronary Arteries. 3. The Efficacy or Power of the Nerves, which is communicated through the Branches of the eighth Pair and intercoſtal Nerve with the recurrent Nerve. Theſe Cauſes concurring produce the firſt Contraction of the Heart, whenever may be the time this firſt Contraction happens, or whatever may be the Cauſe which gives the firſt Impulſe, from whence the Power of the firſt Contraction ariſes. So long as theſe three Cauſes operate in the Heart, ſo long will that Muſcle remain contracted: but in the

very Inſtant of Time in which the Heart is contracted, the Cauſes of that Contraction are deſtroyed or removed. For, 1. The venal Blood, which being received into the Ventricles of the Heart ſtimulate it to Contraction, is all expreſſed into the Arteries. 2. And while the Heart looks pale in its Contraction, it alſo expels the Blood of the coronary Arteries, and the Juices contained in its own muſcular Fleſh, and in the Spaces betwixt the Fibres; and what was in the Arteries it repels into the Aorta, ſince the whole arterial Syſtem of the Heart is without Valves; and the Blood which was in the Veins is at the ſame time expreſſed into the Sinus, right Auricle and Ventricle, paſſing itſelf ſoon after into the Arteries. 3. The third Cauſe of the Heart's Motion is ſomewhat more obſcure; namely, the Heart is ſeparated from all the other Parts of the Body by a membranous Bag, called the Pericardium; nor is there any Communication betwixt the Heart and the other Parts of the Body, except by the four large Veſſels by which the Blood is conveyed from all Parts to the Heart, and from thence to all Parts again. So that from hence it appears, that the cardiac Nerves could take no other Courſe into the Heart, but through the Pericardium by the Sides of the large Blood-veſſels. But there are few of the cardiac Nerves which accompany the Veins, and thoſe which are the moſt powerful and numerous paſs in by the Sides of the Arteries; but the pulmonary Artery and Aorta paſs out of the Heart, joined cloſe to each other; and cloſe by the Sides of theſe two Veſſels, the Nerves of the Heart collect themſelves in two Faſciculi or Bundles, one of which being the larger Plexus follows the Aorta, and the leſſer accompanies the pulmonary Artery quite in a different manner from that in which all other

Muſcles receive their Nerves; for in the other Muſcles the Nerves never enter through the Tendons, but through the Middle of their moſt fleſhy Part, as *Veſalius* has rightly demonſtrated in Oppoſition to *Galen*, and as is truly repreſented in all the Tables of *Euſtachius*. But ſince this is the Courſe of the cardiac Nerves, and the Arteries being more violently expanded at their Beginning by the Blood thrown out of the Heart, than in any other Part of their whole Length, it follows, that the Nerves intercepted betwixt theſe Arteries will be compreſſed; for the Aorta and pulmonary Artery lie ſo cloſe to each other, that they cannot be ſeparated entire without much Labour to the Anatomiſt. But every Muſcle, whoſe Nerve is compreſſed, becomes paralytic or relaxed (§. 401. N°. 4.); and alſo every Muſcle, whoſe Artery is tied or compreſſed, becomes likewiſe paralytic: and therefore when the Heart contracts, it loſes or deprives itſelf of the irritating Blood in its Cavities, as well as that of its Arteries, neceſſary to muſcular Motion, together with its nervous Juice; whence it is evident, that a Relaxation or Dilatation of the Heart muſt neceſſarily follow immediately after its Contraction. But during the time of this Relaxation, the three Cauſes of its Contraction will be again renewed, ſo that a Syſtole will immediately follow its Diaſtole; which Doctrine was taught by no body before it was propoſed by myſelf; and it may be ſeen demonſtrated at large in mathematical Order, as I delivered it in my laſt academical Oration which is publiſhed. For, 1. The Aorta being very full of Blood received from the Heart to the Quantity of four, or at leaſt (to avoid all Diſputes) two Ounces, againſt which Blood the Artery and all its Branches act by their Elaſticity; therefore the Aorta will contract by its own Force ſo ſoon as the Heart has emptied its Blood, and by that means Part of the Blood of the Aorta will be propelled into the coronary Arteries, which being at that time empty will give the leaſt Reſiſtance. 2. So ſoon as the Heart is relaxed, it ceaſes to exclude the venal Blood in the Sinus's and Auricles, in which the Blood was in the mean time collected; and upon the Heart's Relaxation, ſuddenly forces itſelf in the Ventricles, in which there is a ſort of Vacuum, which the Blood itſelf immediately fills. 3. When the large Arteries are contracted, they recede from the mutual Contact of each other, and by that means leave a free Space in which the Nerves lie uncompreſſed, whence more new Spirits will be eaſily ſupplied to the muſcular Fibres which were accumulated above the Compreſſion in the Nerve. But upon the Return of the Power of the Nerves, the Heart itſelf is animated to a freſh Contraction; and as the three Cauſes of the Heart's Motion now return, there is no Obſtacle to its Contraction; but being contracted, a Relaxation will conſequently follow in the manner we before deſcribed. And thus is the proper Motion of the Heart itſelf continued alternately in a different manner from that of all other Muſcles, purely, by the Mechaniſm given to its Parts by the Creator.

[2] This Queſtion is much more difficult to ſolve even than the preceding; nor does the Power or Action of theſe Organs reſult from the Heart, ſince the Heart beats ſix, eight, or ten times within the Compaſs of one Reſpiration.

§. 410. But how great this *Force* [1] is in a contracting Muſcle, he only underſtands, who knows, 1. The Place into which the moving

Tendon is inſerted into the Part to be drawn, with regard to its *Diſtance* [2], from the Center or fixed Point, about which the Motion or Flexure is made. 2. The Obliquity of the Direction through determined *Angles* [3], which are here for the moſt part very acute. 3. The Weight of the Part itſelf to be moved. 4. The *Weight* [4] of the Parts appended, and of that which is to be lifted, together with the Place to which the Weight is applied. 5. The *Duplicity* [5] of the Sum of thoſe Forces required to produce or determine the Motion towards the fixed Point; all which has been mechanically demonſtrated by *Borelli.*

[1] There is no other Meaſure of Forces than by Reſiſtances, in the ſame manner as there is no Magnitude but what is relative and determined by certain Meaſures. But thoſe Quantities are called infinite, which are not reducible to any known Meaſure. And this Power of the Muſcles is determined not only from the Weight of the Limb elevated by the Muſcles, but alſo by computing the Sums of all the Reſiſtances which are to be overcome or removed, in order to produce the Effect. When two ſtrong Men ſtruggle together with equal Forces, there is a great Effort exerted by each, notwithſtanding there is no manifeſt Motion follows: but if one of them prevails ever ſo little over the other, his Adverſary is immediately thrown to the Ground. But that Force by which the Conqueror overcomes his Adverſary, is not barely the Exceſs of the Forces which produce the Effect, ſince a conſiderable Power is exerted to equal the contrary Effort and Reſiſtance of his Antagoniſt.

[a] When Mechanicians determine the Power of a Machine, they make uſe of the Compariſon of Levers, namely, Lines which have neither Breadth, Thickneſs, nor Weight, being altogether inflexible, and ſupported upon ſome fixed Point, called the Hypomochlion, or Point upon which it moves. For altho' there are no Levers having theſe Conditions, yet the Effects are the ſame, ſince contrary Powers deſtroy each other, and as the whole Weight is entirely ſupported upon the fixed Point only, as *De la Hire* has demonſtrated in his Mechanics. Such a Lever they divide, for Inſtance, into four equal Parts, placing the fixed Point or Hypomochlion in the middle, and by placing a Weight at one certain Diſtance from the Center, and a Weight three times leſs at three times the ſame Diſtance, an Equilibrium is produced; and if the latter Power is a little more than thrice the firſt Diſtance, the Weight will be raiſed; but if the Weight is placed at three times the Diſtance, and the Power at leſs, then the triple Power will raiſe the ſimple Weight. But let us apply this Conſideration to the Arm of the human Body, and compare the whole Limb to a Lever, placing the Hypomochlion or fixed Point in the Articulation of the Humerus with the Scapula, for it is in this Articulation that the fixed Point is ſeated, about which the whole Arm is circumvolved. We muſt next conſider the Inſertion of the Muſcle, whoſe Force we enquire after; as, for Inſtance, the Deltoides, which we find is inſerted immediately after the Articulation itſelf; next a Weight is appended, for Inſtance, to the Fingers: now in order to make an Equilibrium, ſo much Force is required in the deltoide Muſcle to raiſe the Weight in proportion as the Diſtance of the Weight is from the Center of

Motion, and the Diſtance of the Inſertion of the deltoide Muſcle from the ſame Center of Motion. But then as the Arm is not a mathematical Lever, but is compoſed of Fleſh and Bones, which are themſelves of no ſmall Weight, the Force of the deltoide Muſcle ought therefore to be ſo much greater than the Weight of the Arm, as the Arm itſelf, than the Diſtance which is intercepted betwixt the Articulation and the Inſertion of the Muſcle, or Application of the Weight, and theſe are to be conjoined, and the firſt Ratio of the Powers is to be increaſed.

3 If now a Weight is applied to ſuch a Lever, as we have before deſcribed, at one End, ſo as to draw the Lever from the Perpendicular, the other End of the Lever will be raiſed with a Force of the ſame Momentum as that by which it was drawn downward, as, for Inſtance, to an Angle of forty-five Degrees; then the depreſſing Power will be ſo much greater than the oblique Power as the right Angle of ninety Degrees, or as the Sine of a right Angle is greater than the Sine of an acute Angle of forty-five Degrees. But if you regard the Inſertions of the Muſcles, they will be found generally inſerted at very acute Angles; as, for Inſtance, if the deltoide Muſcle ariſes directly above the Humerus, and is inſerted into the middle of that Bone towards the Perpendicular, it will certainly make a great Diminution of the Power. Now as this Muſcle is inſerted obliquely into the Bone, it muſt neceſſarily exert ſo much greater Force, as the Sine of its Angle is greater which it intercepts betwixt itſelf and the Lever or Humerus; but if this Angle is diminiſhed or reduced to nothing, and the Weight is applied according to the Direction of the Lever, there will then be a conſiderable Loſs of the Force, that is, if a Weight

is to be raiſed by the Arm in a Poſition parallel to the Horizon, it will require a Force almoſt infinite.

[4] Which Weight is always the greater in proportion as the Power of the Muſcle is applied nearer to the Center of Motion, and therefore the Power muſt increaſe in the ſame Proportion as the Weight exceeds. And therefore the human Arm is not to be eſtimated only at twenty Pounds Weight in calculating the Power of the Muſcles, for it is immenſely heavier to the Muſcles. There are ſome Men who can write Letters upon a Wall with their Arm extended, while at the ſame time they ſuſtain a Weight of twenty or thirty Pounds appended to their Thumb and Fore-finger; whereas to extend the Arm in this Manner with ſuch an appended Weight, requires a Force equal to fifty thouſand Pounds. In the Thigh, whoſe Center of Motion is fixed in the Articulation of the Femur within the Acetabulum of the Os Innominatum, the Muſcles are inſerted ſo near the Center of Motion, that the Forces which they require in order to Motion may be eaſily eſtimated at 100000 Pounds.

[5] This Calculation of *Borelli* has been denied by ſome in *England*. He proceeded in the following manner: Let there be a Pound Weight ſuſpended by a String faſtened to a Hook, I ſay, the String is then drawn with the Force of two Pounds: for the Hook endeavours to raiſe the String with the ſame Force as the Weight endeavours to depreſs it, and therefore a Force equal to two Pounds is applied to ſtretch the String. This is objected againſt by a certain Perſon as a Sophiſm. But he ought to have conſidered, that if the ſame String and Weight was to paſs over a Pully, ſo as to form two Legs, if only one Pound Weight is faſtened

to but one of the Legs, the other will be drawn over the Pully with a Force equal to a Pound, unleſs a like Weight is appended to that End alſo; and therefore from this Conſideration, if the Nail or Hook is taken for the Force of the Pully and one Weight ſuſtaining a Pound, the Hook will appear to operate with a Force equal to the other Pound to prevent it from deſcending; for an Equilibrium would never be produced, unleſs one Preſſure was to be deſtroyed by another in an oppoſite Direction. It is therefore evident, that the Nail will ſuſtain or ſtretch one End of the String as one Pound Weight, while the other Pound which is appended, ſtretches it with the like Force in a contrary Direction, and therefore the whole String will be extended with the Force of two Pounds by appending one. Thus it is evident, that the human Body exerts an immenſe Power to raiſe great Weights; and that to raiſe the Arm, which is ten Pounds Weight, requires a Force of twenty thouſand Pounds. Nor ought we from hence to accuſe the Wiſdom of the Creator, as waſting or beſtowing ſuch immenſe Forces without Neceſſity; for if the Powers were ſo applied, as to act in the leaſt Compaſs with the greateſt Force, the Muſcles ought to have been applied at a very great Diſtance from the Center of Motion, and a fixed Point muſt have been placed out of the Body, which muſt therefore have been like a Tower compoſed of many large Machines; but to avoid this Inconvenience, the Creator did not make uſe of the mechanical Advantages, as they are ſuppoſed to be by Man; but having a full View of his Deſign, and of the Effect to be produced, he has providently diſpoſed every thing to anſwer its Office with the leaſt Diſadvantages, inſomuch that one may very well admire (γεομετρȣντα τον θεον) the Geometry of God, which are the excellent Words of *Plato.*

§. 411. But in what manner the Nerves can derive ſo great Forces to the Muſcles, can be only demonſtrated from *Hydraulics*[1] and Hydroſtatics explained by *Mariot.*

[1] The Increaſe of a Force is almoſt infinite, which ariſes from the moving Power applied thro' a ſmall Tube to a large Receptacle intended to be moved. This entertaining Phænomenon was firſt demonſtrated by *Mariot*, a Perſon born to promote philoſophical Knowledge. I tried an Experiment with the Machine made by *Muſchenbroeck*; it was a cubical Ciſtern made on all Sides with the ſtrongeſt Plate Iron, upon the upper Part of which was fixed a ſquare flexible Plate of Copper: and upon filling this Ciſtern with Water, while to one Side was faſtened a very long Glaſs Tube, like that uſed for a Barometer; and letting out the Air which yet remained in the Machine, by means of a ſmall Aperture furniſhed with a Valve, he placed ſo great a Weight upon the Lid of the Ciſtern, as bent the Copper Plate inward, and then upon pouring one Ounce or two of Water into the Tube, while the Ciſtern contained fifty Pounds, the flexible Lid of the Ciſtern was by that means lifted up, together with a hundred Pounds Weight, ſo ſoon as the Water was a little higher in the Tube than in the Ciſtern. And if a Tube was to be adapted a thouſand times longer, it would eaſily raiſe a thouſand times the Weight, ſo that I could ſafely undertake to raiſe the whole *Stadt-Houſe* or *Exchange* of *Amſterdam* with one ſingle Ounce of Water. For when the Water deſcends through the Tube one Foot, it raiſes the flexible Lid through

ſo much a leſs Space, as the Area of one Foot of the Tube is leſs than a Foot of the Area of the Ciſtern, and therefore the Space run through by the Water makes up for the Smallneſs of its Weight. It is certain that Machines of the greateſt Force may be broke by pouring in a ſmall Quantity of Water, as once happened in my own Houſe, when the Water being froze in a ſtrong Ciſtern incloſed within the Walls, the whole Side of the Houſe and Walls were raiſed by the Force of Water, which ran from the Top of the Houſe through a Pipe into the ſame Ciſtern, which being froze could not vent itſelf. I afterwards avoided the like Inconvenience by making a lateral Opening in the Gutter or Pipe to evacuate the Water which came from the Roof; and hence it is uſual for Builders when they fortify Ciſterns, to leave an artificial Opening to the deſcending Water. We ſee therefore what a conſiderable Force may be exerted by a ſmall Quantity of Water, ſo as to overcome almoſt an immenſe Weight. But the ſame Experiment may be alſo tried another Way. Take a Hog's Bladder almoſt empty, hang it to a String, and let a ſtrong Cord be tied round its Neck, conſtringing it ſo cloſe round a Tobacco-pipe that no Air can paſs betwixt; then let the Bladder, ſuſpended by the String, be faſtened to a Beam with a hundred Pounds Weight appended to its Bottom; then if a Child endeavours to inflate the Bladder through the Pipe with a ſmall Force, the Bladder will be diſtended, and the Weight raiſed. But a greater Weight may be raiſed by the ſame Breath, in proportion as the Bore of the Tube is of a ſmaller Diameter. If in this manner you repeat the Experiment, or faſten ſeveral Bladders to each other, a Child may raiſe above a thouſand Bladders with the like Weight to a moderate Height. But this we find to be the Mechaniſm uſed by the Creator in the Fabric of the Muſcles. A ſmall Nerve is a little Tube, the Blaſt or Inflation is produced by the animal Spirits paſſing through it, the Bladder is anſwered by the expanded Part of the hollow Fibre, the Weight to be raiſed is the Bone, with all the other Reſiſtances. Nor ought it to be objected, that the very ſmall nervous Tubes would burſt by ſuch a Force: for the Force itſelf is very ſmall, by which in the preceding Experiments the Water deſcends. Even in the Caſe mentioned, where the Foundation and Side of the Houſe was elevated, the Pipe which conveyed the Water from the Roof was not at all injured; but when the ſame Pipe was perforated in the Side, the Foundation ſubſided. This may be therefore ſufficient to account for the wonderful Strength or Force exerted by the Muſcles, and every way agreeable to the Circumſtances mentioned at §. 406.

§. 412. But this *Force* [1] of a Muſcle is directed by wonderful and mechanical Aſſiſtances, ſuch as, 1. *Membranous* [2] Swathes or ligamentary Faſciæ, which being broadly expanded, inveſt and confine together the ſubjacent Muſcles and Tendons, as at the Carpus, and in the Foot. 2. Beſides theſe ligamentary Faſciæ, there are alſo others more broad and *muſcular* [3], as in the *Arm* [4], Back, and Thigh. 3. They are aſſiſted by cartilaginous *Pullies* [5], as in the Trochlearis Muſcle of the Eye; or elſe by bony Pullies, as in the Pterygoſtaphylini Muſcles. 4. By one Muſcle tranſmitting and directing another, as in the *Styloceratohyoidei* [6]. 5. By *Hypomochlia* [7], or

Props ſuſtaining, directing, and raiſing the Tendons of the Muſcles, as in the Patella of the Knee, the Oſſa Seſamoidea at the Joints of the Fingers. 6. By broad *Appendages* [8] and *Handles* [9] growing out of the Bones, as in the Trochanters of the Thigh Bone. 7. By the winding round of the Muſcle itſelf *about the Bone* [10], as in the Marſupialis or Obturator internus. 8. By Fat and mucilaginous *Capſules* [11], and Caſes looſely inveſting the Muſcles and Tendons, and always lubricated internally with an unctuous or fat Humour, by which the Motions of the Muſcles are wonderfully aſſiſted and quickened.

[1] There have not been wanting impious Men, who have ſuppoſed that the immenſe Power exerted by the Muſcles, was in a manner thrown away as uſeleſs, ſince the Weight might have been raiſed with a leſs Force in a different manner, whence they take occaſion to accuſe the wiſe Author of Nature: when at the ſame time they do not conſider the great Wiſdom by which the great Architect has avoided the Incumbrance of thoſe vaſt Machines, by which only Men can increaſe mechanical Powers, the human Body being itſelf a Compendium of all manner of Machines moſt advantageouſly diſpoſed.

[2] It was neceſſary for the Uſes of human Life, for the Hand not to be formed of one continued Part or Trunk, but of ſeveral diſtinct Bones variouſly articulated together, each of which might be moved by its proper Muſcle. No Animal has that beautiful Fabrick of the Hand which we obſerve in Man, even Monkeys themſelves not excepted. The Wriſt is compoſed of eight Bones,

the Metacarpus of five Bones, the Fingers of twelve, and the Thumb of two, beſides ſome ſmall Oſſa Seſamoidea. Each of theſe Bones are variouſly and beautifully articulated and ſupplied each with their proper Muſcles. But theſe Muſcles could not well ariſe from thoſe ſmall Bones themſelves; for if ſo, the Hand could not then have had ſo large a Motion, nor would there have been any room for the Reception of ſo large Muſcles, as are required for its ſtrong Motion; therefore the wiſe Creator has made the Muſcles, of the Hand both large and long, agreeable to the ample Motion it required; and yet he has not loaded the Hand itſelf with Fleſh, but he has placed thoſe Muſcles uniformly about the Arm, continuing only their Tendons into the Bones of the Hand. But to prevent the Limb from ſwelling too much, it was neceſſary for theſe Tendons to be inſerted into the Bones, and for the Muſcles and Tendons themſelves to be continued in a right Line; and to preſerve them in that Direction, we obſerve ſtrong tendinous Ligaments placed at the Carpus and Tarſus, under which the Tendons paſs, and are tied down in ſuch a manner, that they cannot be diſplaced. Theſe confining Ligaments are very well repreſented by *Euſtachius* in the Carpus, Metacarpus, Fingers, Tarſus, *&c.* Nor is it neceſſary only for the Phyſiologiſts to be acquainted with theſe Tendons, but they ought alſo to be obſerved by the practical Phyſician, ſince the more frequent Cauſe of the Cramp, which is one of the moſt lamentable Species of Convulſions, proceeds from a diſplacing of the Tendons out of their proper Spheres. Hence the ſtrongeſt Porters, who ſupport themſelves by continual and hard Labour, being troubled with the Cramp, relieve themſelves by faſtening a Leather Strap round the Tarſus and Carpus, in order to make up for the Weakneſs of the confining Ligaments, which are not ſufficiently ſtrong to keep down the Tendons of the Muſcles in their violent Actions. But there are not only common Ligatures of this nature to bind together the Tendons of the Flexors and Extenſors, but every individual Muſcle is confined by its proper Ligament and Capſule, as is repreſented in the Tibialis and Peroneous Muſcles by *Euſtachius.*

[3] The Latiſſimus Dorſi Muſcle, and the fleſhy Part of the Faſcia Lata, paſs into membranous and tendinous Expanſions, which ought to be rather called muſcular Expanſions than real Muſcles. A Capſule of this nature deſcends, from the deltoide Muſcle round the Humerus and Cubitus, ſo as to inveſt all the Muſcles of the whole Arm. But the Muſcles of the Thigh are likewiſe inveſted with a tendinous Expanſion, ariſing fleſhy at the Glutei Muſcles, and denominated the Faſcia lata. But the Uſe of theſe Faſcia is not to move the Articulations, but to contain and ſecure the fleſhy Bodies of the larger Muſcles in the ſame manner as the annular Ligaments keep down the Tendons.

[4] It is from this Faſcia that an Inflammation and Gangrene ariſes, after the Tendon of the Biceps Muſcle of the Cubitus has been injured in Bleeding. And from hence the tendinous Expanſion being injured in a Paronychea, which is continued to the little Finger, the Pain paſſes from thence with the other Symptoms even to the Shoulder. And from hence Wounds inflicted in the Knees, with Pains, Inflammations, Tumors, Ulcers and Gangrenes, extend themſelves from thence even to the Edge of the Os Ilium, namely, theſe Diſorders ſpread themſelves as largely as the tendinous Expanſion it ſelf, which they injure.

[5] When any Weight is to be raiſed heavier than the Perſon's Strength, (for *Hercules* himſelf cannot raiſe a Weight heavier than that of his own Body) or whenever a Body is to be ſo regulated, as to paſs from the Perſon who moves it, it is uſual to twiſt a Rope round a Poſt, or ſome other firm Body, that the Direction of the fixed Point may be oppoſite to the Body which it antagonizes; and by this means very great Weights may be raiſed. There is but one Inſtance in the human Body, in which the Limb is as it were to be moved out of the Body itſelf, as in the Tongue, Eye, *&c.* It was neceſſary for the Eye to be capable of projecting out of its Orbit, as in beholding any thing horrid or frightful, and in amiable Affections turn'd inward towards the Noſe, which is alſo the Poſture when we look at any thing with great Attention; and for this Purpoſe Nature has placed two Muſcles of the Eye in ſuch a manner, as to be capable of thruſting it more or leſs out. There is an annular Cartilage placed more forward, in the upper Edge of the Orbit, than the Globe of the Eye itſelf, from whence the Tendon paſſes, and is reflected back a ſecond time; ſo that when the Muſcle contracts, it does not draw the Eye backward, but forward, or outward towards the Pully thro' which its Tendon paſſes. When ſuch a Pully belonging to a Tendon labours under ſome Defect, a Palſy of the Muſcle follows, which the Phyſician very often unjuſtly aſcribes to the Muſcle itſelf.

[6] The Digaſtric Muſcle of the lower Jaw ariſes much higher than the Part of the Jaw itſelf into which it is inſerted, and therefore it would naturally elevate the Jaw, if it was not for a particular Contrivance, by which its middle Tendon paſſes through an Opening in the Stylohyoideus Muſcle, much lower than the Chin, to which the Digaſtric

from thence aſcends; and thus the lower Jaw is pulled down towards the Os Hyoides. This Mechaniſm obtains in the Tendons of the Muſcles of the Fingers and Toes, called Perforati and Perforantes.

[7] By this Name we call the fixed Baſis or Point which ſupports the moving Power, ſo that it may act; for Inſtance, ſuppoſe a thouſand Pounds in Weight are to be raiſed by the Force of one hundred and fifty Pounds, it is very evident that I cannot eaſily ſo much as ſtir ſuch a Weight unleſs I place an Iron Lever under the Weight, to which the ſubjacent Earth is for a fixed Point; ſo that by depreſſing one End of the Lever, I raiſe the Weight oppoſed to the other End. In the human Thigh there are vaſt large Muſcles, the Rectus, the Vaſtus Externus and Internus, which direct the Thigh in a right Line while they act; but theſe Muſcles are placed ſo much in the ſame Direction with the Thigh itſelf, that they ſeem to have altogether no Force when the Power which draws the Lever in a parallel Courſe exerts no Force in elevating or depreſſing the ſame Lever; and the leſs the Angle of Direction is, ſo much more of the moving Power is loſt, for Powers are as their Sines: hence we ſee that the Patella is added to the Articulation of the Femur with the Tibia, that the fixed Point upon which the Motion is performed might be transferred ſomewhat further, towards that Point to which the Leg is extended. Hence it is that the Patella being fractured, the Knee is perpetually looſe and wavering, ſo that the Perſon cannot tread ſure, and the Patient is obliged to ſupply the Defect with a ſort of Patella made with Steel. The Oſſa Seſamoidea are Hypomochlia or Supports of this kind; and it is from theſe Bones frequently found in the Tendons of the flexor Muſ-

cles of the Fingers, that we frequently find that ſome Men who have ſlender Fingers are nevertheleſs ſtronger than thoſe who have thicker and ſeemingly ſtouter Fingers, that is, with larger Muſcles; but we are not to eſtimate the Force of a Machine from its Magnitude but from its Structure. In the Hare, which is one of the ſwifteſt Animals, there is a Mechaniſm of this Kind, namely, a large Os Seſamoideum placed at the Back of the Foot over which the large Tendons paſs as over a fixed Point, which Point of Motion or Hypomochlium is always large in proportion as the Animal is ſwifter; but other Animals who are not ſo ſwift-footed are deſtitute of this Bone.

[8] The larger Bones have ample Epiphyſes or Appendages at their Articulations, and to increaſe the Strength of each Joint their Heads are very broad, and the Motions of the Joints are always weaker in thoſe Men who have the Epiphyſes ſmaller and more even, as in thoſe who live a monaſtic Life.

[9] There are many who complain of the infinite Number of Proceſſes and Aſperities, deſpiſing the minute Diligence of Anatomiſts who fatigue their Audience with enumerating the infinite Number of Proceſſes and Sinus's or Foramina. But they make this Complaint very unjuſtly, for there is not the leaſt Roughneſs or Inequality of a Bone which is deſtitute of its Uſe, or which does not contribute ſomething to the Motion or Advantage of the Limb. The Thigh could never be moved round, or bent inward or outward, unleſs the Femur was furniſhed with thoſe Proceſſes which are called Trochanters from their turning round, as *Borelli* has very well demonſtrated. Add to

this that the Rotator Muſcles inſert their Tendons into the protuberant Proceſs.

[10] There was no other Place where the Rotators of the Thigh could be fixed, which draw it partly outwards. They certainly could not be placed without the Body, and therefore the Pelvis is ſurpriſingly perforated that the Muſcle itſelf may paſs through a Foramen, and wind round the Femur, by which means the Rotator can turn it outwards, while at the ſame time the Reflection of the Muſcle gives it an Opportunity to be almoſt three times as large as could have been in a direct Courſe; and thus both the Force is increaſed and the Direction obtained which the Nature and Uſe of the Part required. It is a childiſh Opinion that theſe Muſcles are formed merely to ſtop up the Aperture, for the Creator could as well have made it a continued Bone, if this Muſcle had not been neceſſary to be ſeated in that Place.

[11] There is no Muſcle which immediately touches the other Muſcles to which it is adjacent, but every one is inveſted with a cellular Membrane repleniſhed with Fat; and even there are not any two Fibres of a Muſcle, but what are ſurrounded with the adipoſe Membrane; nor is there any Tendon, but what is likewiſe inveſted with the ſame Membrane continued from the fleſhy Body of the Muſcle even unto where the Tendon itſelf is inſerted into the Bone. Theſe inveſting Membranes are very thick and full of Fat about the larger Muſcles, as for Inſtance, the Glutei, pectoral, and vaſti Muſcles, not excepting thoſe that are leſs, which are likewiſe ſurrounded with the cellular Membrane, though not ſo much repleniſhed with Fat as it is about the larger Muſcles. About the Tendons the Fat in this Membrane is rather watery and mucous than ſincere Fat, and the Tendons

move in the midſt of it like Cords included in an oily Caſe. If the adipoſe Cells are deſtroyed, whether this happens in the Muſcle itſelf, or in the Tendon, by a Burn or any other Accident, ſo as to deſtroy the pinguedinous Capſule of the Tendon under the Skin, an Immobility of that Muſcle and Part certainly follows, or the Tendon inſeparably coheres to the Skin. For it is owing entirely to the adipoſe Fabric, that one Fibre is moveable over another; but if by a Suppuration that Fat is deſtroyed which was interpoſed betwixt the Tendon and the Bone, in that Caſe the Tendons cohere even to the Bones, as we ſometimes ſee in the Fingers. Surgeons ought therefore to be cautious in conſuming the adipoſe Membrane too abundantly by Suppuration, eſpecially that which is ſeated about the Capſules of the Tendons, leſt they ſhould occaſion the Tendons to cohere to the Skin, Bones, or other adjacent Parts.

§. 413. But the attractive Force of the Muſcles is very much increaſed, in proportion as the larger Muſcle is made up of many ſmaller ones joined together into one ſtronger Tendon, in which their Forces conſpire; as, for Inſtance, in the *deltoide* [1] Muſcle, the *pectoral* [2], the Biceps of the Humerus, and the Triceps of the Thigh; for the *more numerous* 3 the Fibres, the ſtronger the Muſcle; and the longer the Fibres, the more readily and *largely* 4 do they bend the Joint, while the *tranſverſe* 5 ſmaller Fibres add much to the Conſtancy and Strength of their Motion by confining and ſupporting them together in their proper Situations.

This

[1] This is one of the ſtrongeſt Muſcles, and diviſible into twelve diſtinct ſmaller Muſcles; each of which are again diſtinguiſhable into others ſtill ſmaller, and theſe again each into twelve ſmaller.

[2] I muſt here add an Inſtance of ſurpriſing Strength. A Lion ſeized upon a *Dutchman*, jumping upon his Shoulders behind him; but the Man courageouſly clapp'd his Hand behind him, and ſqueezed the Throat of the wild Beaſt in ſuch a manner, that by ſtopping his Breath all his Strength failed. This Muſcle is alſo like the former, compoſed of many ſmaller ones.

[3] Thoſe Muſcles which are the ſtrongeſt are alſo the thickeſt and ſhorteſt, that a greater Number of Fibres might be contained together in the ſame Space. For one Veſicle is weak, and acts with a ſmall Force, as, for Inſtance, with half a Grain; but when many thouſands of theſe are collected together, they can raiſe many Pounds Weight. For Inſtance, in the Maſſeter, by whoſe Efficacy in a *Turk Veſalius* relates, that an Iron Crow was taken up betwixt his Teeth, and flung with ſuch a Force over his Head, that it ſtuck into the Wall trembling. In the Lion almoſt the whole Head is nothing but Maſſeter Muſcles, and the whole Scull is in a manner preſſed into a Ridge or Spine, ſo as to contain internally but a few Ounces of Brain. But theſe Muſcles are but ſhort, ſince the Diſtance that the Jaw is to be raiſed ſcarce exceeds half an Inch, and therefore ſhort Fibres were ſufficient for this Action, which are upon that account ſtronger. The Heart itſelf is alſo compoſed of Fibres equally ſhort, whoſe Forces are almoſt incredible.

[4] The longer the Muſcle, the larger is its Motion; but then it is ſo much the weaker. *Bernoulli* has demonſtrated, that a hollow Fibre cannot

not be farther diſtended by the Ingreſs of the nervous Fluid, than to be contracted one third Part of its Length. Nor is this difficult to demonſtrate: for a collapſed Bladder cannot be diſtended into any more capacious Figure than that of a Sphere; ſo that if the Thickneſs of a Bladder was nothing before, after Inflation it will be equal to its Diameter. But the Diameter is one third Part of the Circumference; and therefore when a Muſcle loſes in Length, it gains as much in Breadth; that is, one third Part being loſt in Length, will be gained in the Diameter or Thickneſs. Since then the Proportion is but ſhort in which the muſcular Fibres can be diminiſhed in Length, there are therefore long Muſcles for performing ample or large Motions of the Joints, in which Muſcles the Diminution of a third Part of their Length will make a great Difference betwixt the Flection and Extenſion of the Limb. Thus the Motion of the Arms is ample, and therefore the Biceps or Flexor is very long, by which a Motion may be produced anſwerable, which it could not have been by a ſhort Muſcle.

[5] Long Muſcles very eaſily ſtart out of their Places; to prevent which, their long Fibres are collected together by ſmall or tranſverſe ones, which bind together their Faſciculi, being frequently tendinous and very conſpicuous in the Recti Muſcles of the Abdomen.

§. 414. The Action of any ſingle Muſcle may be eaſily known, if we are acquainted with its *Connection*[1], Courſe, or *Direction*[2], and Degree of Mobility in the Parts to which the Tendons are connected.

[1] In order to determine the Action of any Muſcle, we are to examine into its Origin and Inſertion, with the Reſiſtance or Mobility of the two Parts to which it is attached; from whence the Action will be given; and the Motion of the Parts to be inflected, will be in an inverſed Ratio to the Reſiſtances. As for Example: If the Bones A and B are drawn by the ſame Muſcle, and the Reſiſtance of A is as 3, and that of B as 2; in that Caſe the Bone A will be drawn towards B with two Parts of Motion, while B will approach towards A with three Parts.

[2] I have frequently obſerved with Wonder, that Philoſophers and Phyſicians ſhould ſo minutely determine the latent Powers of Muſcles, when there are ſo many things to be conſidered, as render it extremely difficult. In the Marſupialis Muſcle, the interpoſed Hypomochlion alters both the Direction, the Power, and the Action of the Muſcle, reſembling a Cord paſſing round a Pully, and returning in a contrary Direction.

§. 415. Therefore the voluntary Muſcles have Nerves, which ariſe ultimately from the *Brain*[1].

But the involuntary Muſcles which act ſpontaneouſly, and are employed in the vital Motions, receive their Nerves from the *Cerebellum*[2].

The *innate Motion*[3] remaining in the Fibres after Death, depends upon the *ſpontaneous*[4] or involuntary Contraction of their Fibres and Veſſels.

Nor does the Contraction of a Muſcle by any means proceed from their ſpontaneous

Tenſion or Elaſticity, or from the Contraction of their *Nerves* [5].

Although the nervous Juice has a ſtrong Action upon the Muſcle, yet it does not *injure* [6] the ſmall Tubes through which it paſſes, as is evident from hydraulic Experiments.

A Muſcle kept *too long* [7] in a violent Contraction, grows painful, becomes inflamed, and mortifies; the Reaſon of which is evident from what has been already ſaid, and the Truth of it appears from Experiment in a Tetanos.

Muſcles alternately contracted and relaxed, do likewiſe reciprocally admit and expel their Blood with a conſiderable *Force* [8].

The Blood is therefore attenuated, ground together, and *diſſolved* [9], as well in the Muſcles as in the *Lungs* [10]; and therefore the Actions of the Muſcles may, in ſome meaſure, often ſupply the Defect of the Action of the Lungs.

From hence we may judge, why a ſtirring, *active* [11] and briſk Life has different Effects upon the Body, in compariſon with thoſe Effects that follow from a ſedentary and ſolitary Life.

By too much Reſt or Inactivity in healthy Bodies, the accumulated *Oil* [12] compreſſes and diminiſhes the Capacity of the Fibres and Veſſels; whereas an Animal which has been addicted to too much Exerciſe, grows thin and *lean* [13].

Old Age and a laborious Life almoſt change the Muſcles at length into *Tendons*[14], the Tendons into Cartilages, and the Cartilages into Bones.

Laſtly, That there are many *hollow*[15] Muſcles in the Body; the venous Sinus's, the Auricles and Ventricles of the Heart, the Stomach, Inteſtines, Bladder, *&c.*

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[1] Since if this Viſcus remains entire, while there is no Injury offered to the Nerves or Muſcles, all the voluntary Motions are then regularly performed: but when the Brain is corrupted, or labours under ſome other Defect, yet the Muſcles cannot perform their voluntary Motions, even though themſelves and the Nerves remain uninjured, as evidently appears in an Apoplexy ariſing only from a Compreſſion of the Brain, as *Wepfer* has demonſtrated by numberleſs Obſervations.

[2] When the Cerebellum alone is compreſſed, all the Limbs, Muſcles and Viſcera throughout the whole Body ſuddenly loſe their Action, even tho' the Brain itſelf remains entire, and without Injury. But when the Brain only is rendered uſeleſs by a Compreſſure of its Ventricles, while the Cerebellum remains uninjured; in that Caſe all the animal Faculties of Senſation and voluntary Motion are deſtroyed, and yet Life is continued for a conſiderable time after.

[3] For this Force is increaſed after Death, when the ſolid Parts of the Body are more violently contracted by the Cold: but when the Cold is too intenſe, theſe ſpontaneous Motions are very ſmall, being almoſt totally aboliſhed. In the moſt intenſe Cold, the pectoral Muſcle of the Arm can ſcarce move that Limb the Breadth of a Line to-

wards the Breaſt, though it performs one of the ſtrongeſt and moſt ample Motions, while it was warm and well. *Gliſſon* does not therefore make a reaſonable Propoſition, when he ſays that the Muſcles act by a Force ſeated in themſelves; but which Force is more rightly taught by *Bellini* to be ſuperadded to the Muſcles from without themſelves.

[4] In a ſtrangled Animal, which has lately expired by hanging with a Cord, we ſometimes obſerve a Muſcle ſuddenly moves, and continues its Motion for ſome time. The ſame happens if the antagoniſt Muſcle is cut out; and the ſame alſo if a warm Liquor is injected into the Artery of the Muſcle, for by both of thoſe Methods it will be contracted. Now the Cauſe of theſe Motions, which happen after the Death of the Animal, is almoſt entirely the Cold, by which the external Parts that are moſt expoſed are ſtrongly contracted, and by that means their contained Humours are propelled towards the internal Parts, which are not yet deſtitute of their vital Warmth; from whence they are again repelled, ſo as to produce ſome Motions of the Muſcles like thoſe made by the Influence of the Will.

[5] There are ſome Phyſicians who teach that the Nerves act by a vibratory or tremulous Motion, which they receive from their Origin and communicate to the Muſcles, which are by that means put into a ſimilar tremulous Motion; and that from hence ariſes the Contraction of the Muſcles. But we have demonſtrated in another Place (§. 284.), that the Nature and Action of the Muſcles is very different from that of a tremulous Chord, ſince the Nerves are neither tenſe, nor extended in right Lines, free from contiguous Bodies, as is neceſſary for the Vibrations of muſical Chords; nor is it

poſſible thus to explain their Action, on Account of their many Angles and Inflections, without admitting ſome acceſſory Fluid; notwithſtanding a like Explication was attempted by *Steno*, namely, that all the Fibres of a Muſcle do with their Tendons form oblique angled Parallelograms: and that in the muſcular Contraction the Fibres are drawn towards their Origin, change their Angles into more obtuſe ones, ſo as to acquire a ſhorter and ſquarer Figure, by which means as much is diminiſhed from their Length as is added to their Breadth and Thickneſs. Thus did this Anatomiſt think he had accounted for all the Appearances of Motion in the Muſcles, by which they are evidently contracted or ſhortened. But he did not conſider another Theorem in Mathematics, that among Parallelograms, a Square is the moſt capacious, and that the more equal the terminating Lines of a Figure are to each other, the more Space do they contain or circumſcribe; but that their Capacity is continually leſs, as any two of the four parallel Lines are longer than the reſt. Had that Anatomiſt remembered this Theorem, he would eaſily have ſeen from his own Hypotheſis, that to render a Parallelogram ſhorter required a new Acceſſion of Matter to fill up the increaſed Capacity of the Figure.

[6] This is evident in the Tobacco-pipe by which a Bladder is inflated ſo as to raiſe a Weight of a hundred Pounds. A certain Phyſician objecting againſt my Opinion in this reſpect, occaſioned me to make the Machine mentioned (§. 411); but in the Experiment with this Machine he plainly ſaw that the Lid was raiſed with a great Force without breaking the very brittle Tube through which the Water deſcended.

[7] If we uſe any Muſcle too long in walking, carrying any thing, or any other kind of Labour, that Muſcle becomes extremely painful and weak, inſomuch that we rather wiſh for Death, than to continue the Muſcle longer in the ſame Action. The Cramp and Tetanos of the ancient Phyſicians, is a Diſorder in which the Muſcle continues too long in a State of Contraction contrary to the Inclination of the Mind; but if the Muſcle continues too long a time in that manner contracted, a Mortification of it ſoon follows; or even if it is relaxed before, yet a Pain and ſlight Inflammation will continue in the Muſcle for ſome Hours after. The Reaſon of which Conſequences is, that the muſcular Fibres being very turgid with the nervous Juice, repel and exclude all that Blood which was uſually brought into the larger and ſmaller Arteries of the Muſcle; ſo that the whole Vis Vitæ acts with its Force entirely upon that Part of the Artery which is compreſſed; whence ariſes a violent Attrition of the Humours in that Part of the Artery, thoſe Parts only are tranſmitted which are more fluid, while the reſt are compacted into impervious Maſſes, ſo as to generate a true Inflammation, and the ſmalleſt Veſſels themſelves having their Elaſticity and Continuity overcome, are broke or divided by the Force of the impacted Humours. But if again the Force by which a Muſcle is drawn into Contraction has been too long continued, and the Perſon endeavours to relax the ſame, the Motion of the Blood through the Veſſels of the Muſcle will be little or nothing eaſier than before; ſo that its Courſe through the Veſſels will be intercepted, and then ſuch a Muſcle will mortify. By Accident a Man fell into the Water, who being ignorant of the Art of Swimming was ſaved by putting out a long Pole for him to take hold of, which he

ſo violently graſped with Eagerneſs to ſave his Life, that when he endeavoured to let it go out of his Hand, he was not able; for the extenſor Muſcles were not capable of overcoming the Power of thoſe Muſcles which had been too long contracted. Hence it is that provident Nature has made it neceſſary for the Muſcles to be alternately relaxed as well as contracted; the Heart itſelf with the Sinus's and Auricles, the Arteries and Muſcles of Reſpiration are thus alternately relaxed after they have been contracted; and the periſtaltic Motion continues in a Succeſſion, being transferred from one Point to the other, ſo that the Motion ceaſes in one Part while it is renewed in the ſucceeding (§. 93.)

[8] When the Fibres of any Muſcle are contracted, then the Arteries and Veins (§. 406.) which paſs betwixt the turgid Fibres, are compreſſed and obſtructed, the Blood which they have already received is expelled from the ſmaller Veins into the returning Trunk, while the Entrance of the Blood is reſiſted in the Artery above the Muſcle. When the Muſcle relaxes itſelf after Contraction, then the Blood which was excluded and accumulated at the Entrance of the Muſcle, is ſwiftly propelled with a conſiderable Force from the Heart and Arteries, ſo as to paſs into the Veins of the ſame Muſcle, with a Velocity increaſed in proportion as the Reſiſtances of the empty Veſſels was diminiſhed. Thus we ſee in the Heart that after its Contraction the Paleneſs is ſuddenly ſucceeded with a Redneſs throughout every Point, as if the Heart derived the venal Blood into itſelf from the Lungs and all other Parts of the Body. But there is yet another Cauſe why the Blood paſſes more ſwiftly through a moving Muſcle, namely, that, as we have frequently obſerved, the Vein is emptied in

the contracted Muſcle, and by that means readily receives the Blood with a rapid Motion, which was before accumulated and in waiting in order to paſs through the Muſcle. It has been alſo demonſtrated by the *Royal Society*, that Water and Air ruſh into an exhauſted Receiver with a Velocity twenty times greater than that of the ſwifteſt Wind.

[9] The Blood which is accumulated in the Artery before it enters the acting Muſcle, is compreſſed into a ſmall Compaſs by the Impulſe of the ſucceeding Blood, ſo as to form in ſome meaſure a kind of Inflammation; but when the ſame Blood is let free from its compreſſed State into the open Vein which gives no Reſiſtance, the Blood will by that means be three times more highly attenuated, and its Globules will recede in Proportion from their mutual Contacts.

[10] When the Lungs are compreſſed in Expiration, the venal Blood is carried with a ſwift Motion from all the pulmonary Veins into the left Sinus: but the very next Moment after this the Blood of the pulmonary Arteries ruſhes into the empty Veins, by which it rarefies and is reſolved or attenuated by diminiſhing the mutual Contacts of its Particles. But all this holds equally true with reſpect to the Courſe and Attenuation of the Blood through the moving Muſcles.

[11] *Celſus* wiſely obſerves, that Men of Letters, who neglect their Bodies to improve their Minds, are ſubject to continual Diſorders. For in People who live a ſedentary and ſolitary Life, the Blood is only attenuated by the Lungs: but in theſe even the Lungs themſelves perform their Office more ſluggiſhly, ſince the other Muſcles do not urge them on to act, by accelerating the Return of the venal Blood; and therefore in theſe People, this laſt and principal Organ in which the Blood is at-

tenuated is very much impaired. Hence that Thickneſs and impervious Nature of the Blood, by which it is apt to ſtagnate in the ſmaller Veſſels, and from whence ariſes the deteſtable Train of hypochondriacal Diſorders. But Strength and Activity of the Muſcles judiciouſly exerciſed, produces the contrary of all theſe Diſorders. For the moving Muſcles impel more Blood in a given time to the Lungs, by accelerating its Courſe through the Veins; and therefore by exerciſing the Muſcles, the Lungs themſelves are excited to a greater Efficacy in attenuating the Blood. Beſides this, the Muſcles themſelves alſo diſſolve and perfect the Blood, and in a manner perform the ſame Action upon it with the Lungs; ſo that a double Advantage ariſes from Exerciſe, namely, an Increaſe of the Efficacy of the Lungs with the like Action of the Muſcles themſelves. It ought therefore to be a principal Rule with thoſe who ſtudy Knowledge, the Truth of which I have experienced many Years ago, to wit, never to ſet themſelves down to Dinner or Supper, unleſs they have firſt uſed ſome moderate Exerciſe for the Space of an Hour, which was formerly the prudent Advice of *Leonidas.* But yet I would adviſe the Exerciſe of Body to be moderate, and not too violent; for Horſes exerciſed with too ſudden and violent Labour, ſoon periſh.

[12] All People are conſtantly nouriſhed with Milk or Chyle, however various may their Diet be, which is a white, uniform Juice prepared by the vital Powers from the Aliments. But a large and principal Part of Milk is Cream, which being preſſed together forms a fat Oil or Butter; and therefore as the Blood is formed out of Milk, a conſiderable Portion of it will be a true Oil. But all Oil is tenacious, or very difficultly continues

the Motion which it firſt received, and therefore it is repelled by any watery Liqour in which it ſwims; ſo that if it be forced together with Water through a Syphon, it follows ſlowly after the Water in an interrupted and ſluggiſh Courſe with a great deal of Reluctance, inclining towards the Sides of the Tube. In the ſame manner therefore will the oily Parts of the Blood heſitate, unleſs attenuated and urged on through the ſmall Veſſels by the Motion of the Muſcles; and from hence it will be depoſited out of the lateral Arteries, into the Cells, where it will be perpetually accumulated, till almoſt the whole Animal is buried in Oil or Fat; for while the Animal is at Reſt, the Oil is perpetually ſecerned from the Arteries, without any Part of it being returned by the Preſſure of the Muſcles into the Veins. But when the oily Cells are turgid, they compreſs the adjacent Veſſels by degrees in proportion as they are more diſtended; and therefore there is leſs Blood in a Perſon, in proportion as there is more Oil or Fat. I am indeed not ignorant, that the common People, and even many Phyſicians, are perſuaded ſo ſtrongly to the contrary, that you can never induce them to believe, that a Man who appears large or corpulent with Fat, contains leſs Blood than a Perſon who is more thin and lean: but we are certain that every Animal grows ſooner fat, in proportion as it has loſt more Blood, provided the Animal continues in Health; and therefore it is a common Practice with Farmers to bleed their Cattle, in order to haſten their fattening. Women who loſe a conſiderable Portion of the Blood monthly, are in the general obſerved to be fatter than Men: and Animals are not only fattened in a ſhort time by repeated bleeding, but even other profuſe Evacuations of the Humours produce the ſame Effect.

Thoſe who have been ſubject to the repeated Uſe of Purges for a long time in obſtinate Gonorrhæa's, and thoſe who have loſt a great Part of their Juices by a mercurial Salivation, ſo as to melt down and expel almoſt all their Fat, do from an emaciated State very eaſily recover a greater Degree of Fatneſs, after the Perſon has recover'd his Health. Swine, who are perpetually confined in a narrow Stye, are buried in Fat, ſo as to be at length ſuffocated. *Quatit Tuſſis anhela ſues & faucibus angit obeſis.* A Countryman made an Experiment to how great a Degree an Animal might be fattened; and the Animal which I ſaw weighed ſeveral hundred Pounds, being almoſt entirely nothing but Lard: the Viſcera themſelves were compreſſed into a very little Compaſs, and there were only ſome few Threads of muſcular Fibres left of the Muſcles, which appeared red in the midſt of the Lard. The Perſon who has his Blood-veſſels very large in a lean State, will have them three times ſmaller and ſcarce viſible upon growing fat; nor are the Veſſels therefore more numerous in a fat than in a lean Perſon. On the other hand, the Motion of the Muſcles diſſolves the Fat, renders a Perſon lean, and increaſes the Maſs of Blood into which the Oil is returned through the Veins. The commendable Medium therefore ſeems to be for us to uſe ſo much Exerciſe, as to be never ſtuffed up with Fat; and yet not to labour to ſuch a Degree, as to render the Bones and Muſcles conſpicuous through the Skin, that is, to become too lean.

All that has been ſaid concerning the Motion of the Blood from an external Cauſe, namely, the Motion of the Muſcles with regard to Fatneſs, the ſame is alſo true when the Blood's Motion is increaſed by a Fever. For by both theſe Ways the Oil or Fat is attenuated, mixed with aqueous Humours;

mours; and after becoming rank or acrid, it is at length evacuated in Sweats or Urine which have a ſtrong Smell, while at the ſame time the Salts are more exalted or ſharpened, and the whole Body emaciated and conſumed. If you have a Horſe who has been out to Graſs all the Winter, and deſire to bring him to Strength and Labour, exerciſe him prudently by degrees, every Day more and more in the returning Spring; and thus he will acquire a State of Health, and be capable of uſing his Blood and Muſcles in the ſwifteſt Courſes without Damage; and thus you may exerciſe him till he appears to be nothing but Skin and Bones, notwithſtanding he continues in a healthy State; whereas if ſuch a Horſe was at firſt to be ſuddenly uſed with hard riding, it would ſoon kill him. A certain Hare being made wiſe or cautious by dangerous Experience, after having exerciſed the Hounds and Huntſman for many Hours in the ſcorching Sun, at length takes Refuge in the Farmer's Stable, being no longer able to continue the Flight; but unfortunately the Veſſel happens to be wrecked in the Harbour, for the Countryman in ſtirring up the Straw ſeizes the Refugee, and finds the whole Skin quite black from the Turgeſcence of its Blood-veſſels, inſomuch that the Animal muſt have periſhed in a little time, merely from the Swiftneſs and Continuance of its Courſe, which obliged it to reſt.

[14] The Fleſh of the plowing Ox that has been uſed to hard Labour, is ſo tough, and in a manner cartilaginous, that no Perſons can well divide it betwixt their Teeth. Even the Cock, who was a few Years ago ſo tender a Fowl, becomes at length feeble, and the Muſcles and Tendons of his Legs become bony, and thoſe of every other Part proportionably tough. The muſcular Fibres of the

Stag, which has been fatigued by chaſing, are juiceleſs, and almoſt like thoſe of Wood, while Part of the Heart itſelf is converted into a real Bone, not without conſiderable Detriment to the Animal; which Bone is what the *Arabian* Phyſicians recommended to prolong Life. In a very old Man, who has been perpetually addicted to Labour, the Muſcles of the Back, namely, the Semiſpinalis, Longiſſimus and Sacrolumbalis ſcarcely retain the Nature of a Muſcle, but become indurated like the Tendons of the Bones; while the Bones themſelves become hardened and more compact than they naturally ought to be, as is evident from the diſappearing of the Sutures, ſo frequently obſerved in the Skulls of old People. At the ſame time alſo the Tendon in the Septum of the Heart itſelf begins to turn into Bone, and ſo does likewiſe the Beginning of the Aorta and pulmonary Artery by degrees acquire a cartilaginous Nature. *Willis* alſo obſerves, that the jugular Veins and their larger Sinus's become indurated in this Manner; and if Age continues, the carotid Arteries themſelves, and then the falciform Sinus of the Dura Mater oſſify. From hence therefore it appears, that barely by muſcular Motion continually and immoderately uſed, all the ſmalleſt Veſſels are firſt rendered impervious, and afterwards quite obliterated or turned into compact Fibres. But that Cauſe of Immobility which ariſes from too much Reſt or want of Exerciſe is of a very different and oppoſite Nature, notwithſtanding they both produce the ſame Effect. We have frequently obſerved Men who having broke their Arm have been commanded to perpetual Reſt by their unſkilful Surgeon, the Limb in the mean time being kept immoveable and in the ſame Poſture for the Space of ſix Weeks, when he briſkly removes

moves the Dreſſings with high Expectations of his Reward, but unluckily he finds the whole Arm immoveable. The conſtituent Particles or Elements of our nervous Fibres ſeem to be of that Nature, that if the Fibres continue too long without being expanded by the Impulſe which the Spirits make in their Contraction, the Elements by that means acquire too great a Coheſion, whereby they become diſobedient to that Force by which they were before contracted, whence their Motion is at length utterly deſtroyed. But by an alternate Exerciſe and Reſt, the Strength of the ſolid Elements, as well as their due Mobility or contractive Nature, is preſerved at the ſame time, ſo as to render the Muſcles as active as poſſible.

[15] The Heart, Auricles, and venous Sinus's, the Sinus of the Vena Portæ, all the Arteries, the Stomach, Inteſtines, Pelvis of the Kidney, Ureters, urinary Bladder, Uterus, *&c.* are all hollow Muſcles, and receive their Nerves from the Cerebellum, and are not ſubſervient to the Influence of the Will.

* * *

The Function of the Skin.

§. 416. ALL [1] the *Muſcles* [2] of the Body are covered under the Skin with a thin cellular Membrane, furniſhed with *Arteries* [3], Veins, Nerves, lymphatic Veſſels, and *oily Cells* [4], as alſo with ſome muſcular Fibres diſtributed here and there through its Subſtance, to render its Fabric the more capable of receiving and expelling the oily Parts of the Blood. This Membrane is extremely *dilatable* 5, inſomuch that it may be enlarged almoſt to any Bulk; its chief Office being to collect the Fat, which is yet only a *thin Oil* 6 ſtagnating in the *round* 7 Cells of this Membrane. This oily Fat being ſeparated by a ſlow Motion of the Blood paſſing from the ſmall Arteries opening into the contiguous Cells, ſerves to defend, lubricate, and anoint the Muſcles, which are not only each of them furniſhed with a Membrane of this Subſtance, by which they are diſtinguiſhed from each other; but alſo the ſame cellular Subſtance, intermixing itſelf betwixt the *Fibres* 8 of the Muſcles, ſeparates each of them from the other: but its contained Oil not only ſerves to facilitate the Motion of the Muſcles and their Fibres, but alſo by returning into the Blood, it ſerves to temperate the *Acrimony* 9 of all the Juices, and prevents the bad Conſequences which might ariſe from a too violent Motion of the Blood, as well as of the Muſcles themſelves; and when this Oil has been diſſolved by Heat and Motion, it may by Preſſure enter into the ſmall adipoſe Veins, and by them paſs to thoſe Parts where it is wanted, ſo as to mix with the *venal* 10 Blood in a more ſubtilized State; it may be queſtioned whether it does not exhale after having performed its Office? But we are certain that the Skin and Cuticle are moiſtened with an oily and unctuous Subſtance like Fat.

[1] The Creator has determined the particular Bounds of the human Body, which it can exceed either not at all, or but a very little. Internally the Magnitude of the Body is limited by the Bones; while externally its Bulk is determined in a great meaſure by the Fat, which varying in its Quantity required to be reſtrained within Bounds by the Skin, being one principal Office of that common Integument, which is of all others in the human Body the moſt tough and compact. But it was neceſſary for the Skin to be ſo formed as to diſcharge the Matter of Sweat, with the oily or ſebaceous Matter, and to be freely perſpirable, as well as to form the Organ of Touch. To perform all theſe Offices, it was neceſſary for the Skin to be furniſhed with Nerves and Veſſels of divers Kinds. Theſe Veſſels are covered externally with a Cuticle in ſuch a manner, that there is not one Papilla of a Nerve, nor any ſingle Vaſcule expoſed nakedly to the Air. But the Skin not only diſcharges Vapours externally, but it alſo inſpires moiſt Vapours which it attracts from the Air. I am perſuaded, that as there are daily five Pounds of Moiſture diſcharged from the Body in a Day by inſenſible Perſpiration, ſo on the other hand there is a large Quantity of moiſt Vapours abſorbed, which are taken in by inſenſible Inſpiration, not in a much leſs Proportion than that of the expirable Vapours. A very wiſe Phyſician, who attended the Health of the Prince *De Montecuculi* at *Vienna*, related to me an extraordinary Caſe of a dropſical Woman, who though ſhe took little or no Drink had nevertheleſs a daily Increaſe of the Water, and diſcharged large Quantities by Urine. As the Reaſon of this Appearance was obſcure, the Emperor ordered Watches to be ſet by the Woman, that there might be no Fraud in the Caſe by giving the Woman any Drink private-

ly; but it appeared that there was no Deceit in the Caſe. If we admit abſorbing Veins, there will not appear any thing ſurpriſing in this Event: for we may eaſily conceive more Moiſture to have been abſorbed from the Air by the Veins than was diſcharged by the Arteries. And hence we have a Reaſon why we become thirſty in dry Weather, and require little Drink when the Air is moiſt; namely, for that though we equally perſpire, yet in a dry Air leſs Moiſture is abſorbed, whereas in a moiſt Air there is a much larger Quantity of Humidity taken in. Therefore *Sanctorius* does not appear to have determined the whole Meaſure of the perſpired Moiſture, ſince he deduced his five Pounds only from the Weight of the Aliments which were taken into the Body; whereas the Proportion of the perſpirable Matter may be much larger upon the Account of what is abſorbed; inſomuch that if he had added the Quantity of Moiſture abſorbed to that which is expired from the Aliments, he might doubtleſs have brought the Proportion of perſpirable Matter to be to the Meat and Drink as ten to eight. Nor is it difficult to account for the extraordinary Increaſe of the Water in the dropſical Woman of *Vienna*, if you conſider that the bibulous Veins never ceaſe from their Office, whereas the Arteries may be ſo weakened by a Deficiency in the Vis Vitæ, as not to be capable of perſpiring as much as the Veins abſorb; and thus a Body may become dropſical even under the drieſt Courſe of Food.

[a] The Muſcles are not covered with any common Integument beſides that of the Panniculus Adipoſus, that is, not with a common muſcular Membrane inveſting all the Muſcles under the Skin; but the cellular Membrane not only covers the Muſcles externally under the Skin, but is alſo

inſinuated betwixt every particular Muſcle, and even betwixt every one of the Faſciculi of their Fibres, as well as between every individual Fibre itſelf down to the ſmalleſt.

[3] *Ruyſch* demonſtrates that Part of the Skin and Fat which lies next to the Muſcles to be one continued Net-work of Arteries and Veins, beſides which nothing elſe can be obſerved in emaciated Bodies. If you inject Water into the Veſſels of the Skin, ſo as perfectly to waſh out the Blood, and then inject thoſe Veſſels with Wax, you will be ſurprized to find what a Number of Veſſels are ſupplied to the Skin from the cellular Membrane, which is expanded beneath; that is, by filling all the cutaneous Arteries and Veins, as well as thoſe of the cellular Membrane itſelf.

[4] The ſmalleſt ſanguiferous Arteries and Veins communicate with the oily Cells, which again open laterally into the adjacent Cells, into which the oily Part of the Blood is depoſited, as it paſſes through all the ſmall Arteries, and cannot find a ready Entrance into the Veins; but creeping along the Sides of the Arteries, it ſlips into the lateral Ducts or Mouths of the Cells, where it is continually accumulated to a conſiderable Quantity. For even ſuppoſing but one Particle of Oil, equal to the hundredth Part of a Grain, to be daily depoſited in the cellular Membrane, it may by that means be expanded in a few Days to an immenſe Bulk; but if a Humour thinner than Oil paſſes into theſe Cells, it may be eaſily preſſed out again into the Arteries, and be from thence conveyed into the Veins. In lean Animals there is little or no Oil found in theſe Cells. If a Hog is killed early in the Spring without having been fed, he will be found ſo lean and poor, that the red Muſcles will lie cloſe to the Skin: but if you confine the Animal,

mal, and kill him in the Autumn following after fattening, you will then find an Interval of Fat ſometimes to the Thickneſs of a Hand's Breadth, interpoſed betwixt the Skin and the Muſcles, in which neither Arteries nor Veins can be perceived; being a mere Oil collected in the Cells. From theſe Cells it is that the adipoſe Membrane has acquired the Name of Cellular.

[5] Hence it is, that by Inflation into this Membrane the Bulk of the Animal may be increaſed to almoſt three times its uſual Dimenſions: but then the Flatus is to be impelled either in the Forehead, or in the Scrotum, where there is but little Fat. Several Phyſicians have made Experiments by inflating all Parts of this Membrane in Animals, excepting only in the Palms of the Hands and Soles of the Feet, where the Cells of the Membrane are too tough or tendinous to give way to the Flatus. I have ſometimes obſerved the Eyelids diſtended in the Small-Pox by the Inflation of this Membrane to the Thickneſs of two Fingers Breadth, the Tumor appearing pellucid. I ſaw a calculous Patient ſo fat, that the adipoſe Membrane was ſix Inches thick at the Navel, and the Kidneys themſelves were compreſſed by the Fat, which was one principal Cauſe of the Stone in them.

[6] The *Galeniſts* diſtinguiſh betwixt Sevum and Adeps, the latter of which only they admit in the human Body; but it is certain, that only the Horſe and human Species have that kind of Fat which is a fluid Oil, and which after Death becomes a little more conſiſtent.

[7] That the Cells have a round Figure, we learn from the Diſtention of them by any tenacious Matter, as in the Fat of Swine, which have the Diſeaſe properly termed the Meaſles; that is, when a more

a more thick gelatinous Liquor is depoſited and inſpiſſated in the Cells, inſtead of the more fluid Oil: Beſides this, if a Portion of this Membrane be inflated and dried in ſuch a manner, that the Cells may be able to ſupport themſelves from collapſing, upon viewing them with a Microſcope, you will perceive round Cells, like the Honey-bladders in Bees.

[8] Even there is not one ſingle moving Fibre deſtitute of its oily Covering. The Heart itſelf is often buried in Fat, and the Beginning of the principal Arteries are alſo inveſted with the adipoſe Membrane. But where the Muſcles are ſmaller, this Membrane is thinner: ſo that in the Forehead, Occiput, Scrotum, Face, Hands and Feet, there is very little Fat, in proportion to the thin muſcular Expanſions which are there ſeated; but in the Arm, Thigh, Abdomen, *&c.* the Muſcles are ſtrong, and inveſted with a large Quantity of Fat or Oil, ſerving to lubricate the Fibres, and prevent them from drying.

[9] Fifty Pounds of Fat have been obſerved to be waſted in a ſhort Space of time by a Fever.

[10] There are an infinite Number of Experiments, which demonſtrate this Communication betwixt the Cells and the Veins. If a fat Horſe be immediately taken out of the Stable after a long time of Idleneſs, and gradually addicted to more Labour every Day, he may within the Space of three Weeks be reduced to ſuch a State of Leanneſs, that the Skin will adhere to the Bones; and again, if the ſame Horſe ſtands idle all the Winter, he will recover his former Fatneſs. But when the Vis Vitæ is ſo weak, as to be ſcarce able to propel the Humours forward through the Veſſels, then the Blood abounds more with Water than Oil; which Water eſcapes into the empty Cells of the

emaciated Animal, ſo as to diſtend the Cells which inveſt the Muſcles, and produce a Leucophlegmatia, and as much of this Water is accumulated in the cellular Membrane under the Skin, as we ſometimes obſerve of Fat; for in the Anaſarca, the Muſcles themſelves never receive the Water, but the cellular Membrane only, which is ſpread betwixt the Muſcles and the Skin. But the Cells of this Membrane, where-ever ſeated, have all of them a Communication with each other throughout the whole Body. Take the following Experiments, from whence you may believe the Truth of this Communication. In the Memoirs of the Academy of Sciences, *Anno* 1713, there is an Inſtance of a Man, who by a Fall broke ſeveral of his Ribs, which wounded the incumbent Parts ſo as to admit the Air into the Cavity of the Thorax: but upon the next Day the whole Skin of the Body appeared inflated, except the Palms of the Hands, and Soles of the Feet. In the Hiſtory of an uncommon Diſeaſe which I publiſhed, there is an Inſtance of a Rupture in the Oeſophagus; but the Oeſophagus is inveſted with a cellular Membrane, which communicates with the Pleura and Diaphragm in the whole Body. Hence the Air which was ſwallowed, paſſed out of the lacerated Gula into the cellular Membrane, which being inflated, produced an emphyſematous Tumor throughout the whole Body. There was a certain Plaiſterer ſo dropſical, that he ſeemed to be buried as it were in a Caſe of his own Skin, ſo as to be almoſt concealed, his Legs equalling the Thighs of a healthy Man. Being very cold in a ſevere Winter, he brought his Body too near a great Fire, and applied his ſwelled Legs to the burning Coals without any Senſe of their being burned; and thus the Skin being perforated, the whole Quantity of Water, which was accumulated from Head to Foot throughout the whole Body in the cellular Membrane, was evacuated thro' the Wound. Thus by a fortunate ill Accident, the Patient was cured of his Diſorder, ſo that in three Days time the Skin hung like a looſe Cloth about his Body. Here therefore the Communication evidently appeared betwixt the Cells of this Membrane in all Parts of the Body, in which the Water was collected. The ancient *Egyptians* being acquainted with Events of this Nature, did not perplex dropſical Patients with internal Medicines; but they paſſed a Needle and Thread thro' the Skin, leaving the Thread in the Wound to prevent it from healing, and thus the Water continually flowed out Day, and Night. When Butchers intend to free the Skin from the Fleſh of Sheep or other Animals without wounding either, they uſually make a ſmall Inciſion in the Skin, and blow Wind underneath the Skin into the cellular Membrane; after which they drive the Flatus from the Head to the Foot betwixt the Skin and Muſcles, which are by this means more neatly freed from each other; which is a manifeſt Sign how ample and ready a Paſſage there is through the Cells of this Membrane communicating with each other.

§. 417. Immediately upon this Stratum of Fat (§. 416.) is ſpread a thick Intertexture of ſubcutaneous *Nerves* [1] rendered very thick and *tough* [2] or ſtrong by the hard Integuments of the Nerves; beſides which, there are alſo numerous *Arteries* 3, Veins, and lymphatic Veſſels, interwove together with the Nerves throughout the whole interior Surface of the

Skin; from which Veſſels the other ſmaller ones ariſe, which are ſeated on the extreme Surface of the Skin.

[1] Throughout every Part of the Body where the cellular Membrane is expanded, either in a more or leſs conſpicuous State, as it is more or leſs diſtended, there are many ſmall Nerves diſtributed, which *Vieuſſens* confeſſes himſelf to have been never able to delineate, notwithſtanding he formed Tables of an unuſual Magnitude to expreſs them with Truth. But it is eviden from his Tables that no fewer Nerves are ſent to the Skin than to the ſeveral other Parts of the Body. But *Euſtachius* expreſſed them with Truth above two hundred Years ago, as is evident from his Tables which have been lately diſcovered. The ſubcutaneous Nerves are therefore collected together, after having paſſed through the cellular Membrane, and uniting with each other in great Numbers, they are at length erected upright in the Skin; whoſe Toughneſs or Calloſity ariſes from the Dura Mater, which the Nerves throw off in order to form the Papillæ.

[2] This Intertexture of hard Fibres is uſually called the Skin itſelf, which being very tough is not eaſily penetrated by the Knife of the Anatomiſt, conſiſting almoſt entirely of Nerves, very ſtrictly interwove and compacted together in an intricate Manner. But the Leather which we make uſe of is little more than the Nerves and ſmall Veſſels with the Integuments of the Nerves; for as to the ſoft and real Subſtance of the cutaneous Nerves, that is deſtroyed by the Artifice of Tanning.

[3] The ſmall Arteries of the Skin are extremely numerous; nor do they extend beyond the Skin: for *Ruyſch* could never diſcover any Veſſels in the reticular Body.

§. 418. But the ſmall Nerves of the Skin which *ariſe* [1] perpendicularly outwards from its fibrous Intertexture, form ſmall Pyramids, which depoſiting their external Integument received from the Dura Mater, by that or the next Integument which they caſt off, is formed the reticular Body of *Malpighi*, which he firſt diſcovered in the Feet, Hands, and Tongue; but theſe Papillæ are more accurately repreſented by *Ruyſch*, who has demonſtrated them throughout almoſt every Part of the Body; only the Papillæ are different in various Parts, and the reticular Body is perforated with as many Foramina as there are ſoft nervous Papillæ ariſing up, which are tranſmitted, ſecured, and retained in order by the reticular Body. But theſe Papillæ appear the moſt numerous and conſpicuous in thoſe Parts where the Senſe of Feeling is the moſt acute, as in the Tongue, Nipples of the Breaſts, the Glans Penis, Vagina, and Labia of the Pudenda in Women, the Oeſophagus, Stomach and ſmall Inteſtines, in which Parts they are deſtitute of a thick Cuticle, and are but juſt covered with an exceeding fine Expanſion continued to the external Cuticle; they alſo appear very conſpicuous in the Ends of the Fingers and Toes, where they are indeed covered with a Cuticle, but ſomewhat thinner than in the other Parts of the Hand; but in all other Parts of the Body they are inveſted with a thicker Skin, appear ſmaller, leſs numerous, and are not ſo ſenſible. Laſtly, the reticular Body itſelf appears to be entirely *deſtitute* [2] both of ſanguiferous and ſerous Veſſels; and the Papillæ themſelves appear leſs and not ſo ſharp pointed after the Cuticle has been pulled off.

[1] The ſmall Nerves which are hard in the Skin through which they are diſtributed, join their Integuments together, and becoming ſoft, naked, and deſtitute of their Integuments which they throw off, they riſe up perpendicularly outwards in all Parts of the Skin, and form ſhort ſlender Tubercles, which are the pulpy and true medullary Subſtance of the Nerves themſelves in a pyramidal Figure, being uſually called Papillæ from their accumulated Appearance like the Nipples of the Breaſts, or like the Horns of Snails, conſtituting the immediate or true Organ of Touch, which *Malpighi* allowed only to be ſeated in the Tongue and Ends of the Fingers and Toes, but *Ruyſch* has demonſtrated, that the pyramidal Papillæ for the Senſe of Feeling are found in great Numbers throughout every Part of the Skin, as well as in the Lips, Breaſts, *&c.* and that in the Noſe they perform the Senſe of Smelling, that of Taſte in the Tongue, and of Feeling or Touch in the twenty Ends of the Fingers and Toes. They are ſo extremely ſenſible as to contract themſelves upon the ſlighteſt Touch of any Body externally. When a Bliſter is raiſed in the Skin either by Fire or Cantharides, at the Bottom of the Bliſter a very ſenſible Jelly appears, which is the reticular Body intermixed with the nervous Papillæ. But thoſe ſmall Nerves which are changed into Papillæ, throw off their external Coat in ſuch a Manner, that they lie at a ſmall Diſtance from the Ends of the Papillæ, and form the reticular Body ſo

called from its many Perforations through which the Papillæ are tranſmitted, and which Foramina are very conſpicuous after the reticular Body has been taken off from the Papillæ. It is therefore not difficult to conceive, that there are as many Caſes or Sheaths in the reticular Body, as there are Extremities of the Papillæ, in the ſame Manner as a Glove is furniſhed with as many Partitions as there are Fingers: and hence it is that in the ſmall Fiſſures or Lines of the Skin, the reticular Body which receives the Papillæ is very thin in compariſon with its Thickneſs in all other Parts. This Body is therefore immediately covered externally with the Cuticle, and it is only the external Surface of this which appears black in the *Ethiopean*, brown in the *American*, and white in the *European*: for the Cuticle itſelf in black People appears white, as we plainly ſee when it has been raiſed by a Bliſter. Internally the reticular Body adheres to the cutaneous Nerves; and therefore the Cuticle is the firſt common Integument that inveſts the whole Body; next to which lies the Corpus Reticulare of *Malpighi*, as the ſecond Integument which we have here deſcribed; the third common Integument is the true Skin itſelf, and the fourth is the adipoſe Membrane. If you abrade this reticular Membrane, the ſhort and ſoft Papillæ will appear naked and diſpoſed in the Capſules of the reticular Body, to which the tactile Nerves and numerous Veſſels are diſtributed; but under the Papillæ follows a tough hard Integument compoſed of the cutaneous Nerves, being the moſt material Part of the Skin itſelf, immediately after which follows the cellular Membrane before deſcribed (§. 416.).

[3] The reticular Body ſeems to have Veſſels, though none can be demonſtrated by any Art,

becauſe they are much ſmaller either than the ſerous or ſanguiferous Veſſels; but that there are Veſſels ſeems to follow from that kind of Leproſy which is called Elephantiaſis.

§. 419. From the ſaid nervous Intertexture ariſe perpendicularly ſmall ſharp-pointed tough Threads in ſeveral Parts, which conjoining together from a bulbous Root form thoſe Bodies which we call *Hairs* [1]; but ſome of theſe Hairs ariſe immediately out of the *Fat* [2] itſelf, at conſiderable Depth, either from the Cells or ſmall Glands which are interpoſed in that Membrane, and being propelled outward become gradually drier in the Air, often running for a conſiderable Length thro' confining Capſule or Sheaths; and theſe Bodies or Hairs ſerve to defend the Skin, faſten and ſecure the *Pores* 3, and to anſwer particular Purpoſes with regard to the Skin in various other Parts, as in the Cavities of the Noſtrils or external Noſe, *&c.*

[1] Theſe Bodies or Hairs take different Denominations according to the particular Part where they are ſeated. In the Chin they are called the Beard, in the Eyelids Cilia, over the Eyes they are called Brows, in the back Part of the Head they are called Capilli, in the Noſtrils Vibriſcæ; and there are ſtill others at the Pubes and in the Armpits, which with thoſe appearing all over the Skin, are only diſtinguiſhed by the common Appellation of Hairs, which yet are not to be found in thoſe Parts which Nature has deſtined to a perpetual Attrition, as betwixt the Fingers, the Palms of the Hands, *&c.* Even in the young Infant, the Female as well as

the Male at the time of Birth, the whole Skin appears beſet with fine Hairs like the Down of a Peach, which viewed with a magnifying Glâſs appears like ſoft Wool. The People of barbarous Nations which inhabit towards the North are covered all over with Hair, and this was the Condition of *Nebuchadnezzar*, who being afflicted with Melancholy by divine Power, neglected his own Body. But the Hairs may be diſtinguiſhed into two or three Claſſes; the firſt of which may compriſe all thoſe which ariſe with bulbous Roots from the adipoſe Membrane, and the ſecond the ſhorter Hairs which do not perforate the Skin but ariſe immediately from it, ſeeming to be a Production of the Extremities of the Nerves themſelves, namely, a Continuation from the cutaneous Papillæ (§. 418.), each of which are compoſed of a very ſenſible Nerve paſſing through the reticular Body, after which they ſend off a Filament which perforates the Cuticle, and from thence derives a kind of Sheath through which it paſſes to the open Air, where loſing its ſoft and ſenſible Nature, it becomes quite deſtitute of Feeling; and that the Filaments which are continued from the Papillæ are thus conjoined together into Hairs, is demonſtrated by the Experiments of *Ruyſch*. If a Portion of the Skin which has been injected, is macerated for ſome time in Water, it will be no difficult Matter to ſeparate the Cuticle, in which the Foramina will appear that traſmitted the Hairs; but it is from the Cuticle that the Vaginæ or Sheaths are derived to the medullary Part of each Hair; and therefore when a Hair is pulled out it tears off Part of the Cuticle, and appears to have a round bulbous Root which was ſeated in the Skin itſelf. The Hairs are therefore not a mere Continuation of the Cuticle, but they only perforate it, and derive an external Covering from thence, being themſelves continued from the medullary Subſtance of the Nerve, from whence ariſes that Titillation produced by a gentle Extenſion of the Hairs, and which is ſo conſiderable in the Noſtrils as to produce Sneezing; and even if but one ſingle Hair is gradually pulled out of the Skin, either in the Beard, Eyelids, Noſtrils, *&c.* it excites the moſt intenſe Pain; but if they are pulled out inſtantly, the Pain is then but for a Moment, ceaſing almoſt as ſoon as it is felt. The Hairs are ſpeedily renewed in the ſeveral Parts in which they at firſt grew, from the ſame Cauſes by which the Nails are produced. 2. Another Claſs of Hairs are thoſe which are very long, and continued in a curling or twiſted Courſe, as are thoſe Hairs which are moſt expoſed to the Air, which we ſee in People who ſuffer their Beard and Hair of the Head to grow to their full Length, but of which we deprive ourſelves by ſhaving cloſe to the Skin. 3. We may again diſtinguiſh a third Claſs of Hairs ſeated in thoſe Parts of the Body which are in the greateſt Danger of violent Attrition, as in the Scrotum, Pubes, Arm-pits, *&c.* which Hairs inſert their Roots obliquely for the Length of two or three Lines within the Fat into a ſort of ſubcutaneous Glandules, leſt if they had been rooted not ſo deep but in the Skin itſelf, they might by the Contraction and Motion of the Skin, have been ſo agitated as to produce Pain, as for Inſtance, in the Scrotum, *&c.* Theſe Hairs alſo excite a Titillation and Itching, by which they advertiſe the Animal of Inſects harbouring among them; and they alſo exclude Inſects from entering the Noſe, Ears, Eyes, *&c.* in which Parts they ſoon grow again after they have been deſtroyed. When the Hairs in the auditory Paſſage have grown ſo long as to touch the ceraminous Matter which lines that Cavity, it excite a wonderful kind of Titillation or Itching, whereupon the Perſon immediately endeavours to cleanſe the Ear. For the ſame Reaſon Swine who have the Organ of Hearing ſeated very deep, love to rub their Ears againſt any Obſtacle; and if it was not for this Senſation of Itching excited by the Hairs, the auditory Paſſage might grow together to be ſtopped up.

2 At certain Intervals in the Skin are ſeated Oil-Ducts, from whence the Head becomes all over greaſy if it has been covered up for ſome Days; which Oil not only lubricates the Skin but alſo the Hairs, both which are likewiſe moiſtened by the Humidity of the perſpiring Veſſels. But how neceſſary this Liniment is to preſerve the Hairs, we are taught by the Diſorder called Trichiaſis, in which the Hairs becoming too dry, ſplit into many ſmall Threads. The *Eaſtern* People are very induſtrious in anointing the Hair of their Heads, which was a Ceremony formerly obſerved in the making of Prieſts and Kings. Perhaps this Cuſtom might have been derived from the bad Conſequences which they obſerve to follow from too great a Dryneſs of the Hairs. But beſides this there is a kind of Exhalation in the Head different from that of all other Parts; for we there obſerve thoſe Tumors which are called Talpæ, whenever the oily Cells have their excretory Ducts obſtructed, ſo as to be themſelves diſtended by the perpetual Accumulation of their contained Humour from the Arteries, inſomuch that they have been ſometimes obſerved large enough to hold three Ounces. Some improperly call this Diſorder a ſcald Head, whereas it is a true kind of Atheroma. From hence we may underſtand

the Reaſon why cutting and ſhaving off the Hair of the Head produces a Change throughout the whole Body, and why removing the Hair in this Manner from the Head, often cures or at leaſt eaſes intolerable Pains of this Part, which yield to no other Remedies; as is confirmed by daily Experience in *France*, *Italy*, *Spain*, and *Britain*, and as we are aſſured alſo by *Sydenham*.

[3] The Skin viewed with a magnify Lens appears full of Furrows in the Hand and Feet, not only diſpoſed in thoſe large Ridges which we perceive with the naked Eye, but alſo in leſſer ones which traverſe the former. Betwixt the Furrows there is an intermediate Space filled with a Ridge or a Bank. But the ſmalleſt Particles which the Eye can diſtinguiſh by the Glaſs are a ſort of Scales, by the Connection of which together, the Cuticle itſelf ſeems to be formed, through which open an infinite Number of exhaling Veſſels. The Hairs paſſing through the Cuticle are a ſort of Stakes or Pins, to confine the Pores in their proper Order, that they might not be diſplaced and diſturb each other; and this may be one of the principal Uſes of the Hairs, which alſo ſerve to keep the Skin warm, defend the Cuticle from Attrition, to ſerve as a Skreen to keep off Duſt and Inſects from the Eyes, Ears, Noſe, *&c.*

§. 420. But from the innumerable ſmall Branches, of the ſubcutaneous Arteries which are interwoven together, ariſe very ſubtle Veſſels opening outwards, and which in a State of Health continually *exhale* [1] a thin volatile, odorous, ſaline and inviſible Vapour from under the *Cuticle* [2]; but when theſe minute Ducts are relaxed, or the Humours too forcibly impelled,

led, the inviſible Vapour is then diſcharged in the ſenſible Form of Sweat.

[1] This Vapour may be demonſtrated to the Eye by Experiments. If the Arm of a healthy Man that has been waſhed clean, is inſerted into a clean Glaſs with a long Neck, you will be ſurpriſed to ſee the Quantity of Liquor, which in a quarter of an Hour's time will be condenſed on the Sides of the Glaſs, which will trickle down the Sides to the Bottom in the Form of a limpid Water having a little ſaline Taſte, and ſomething of a fœtid Smell. The Cuticle is therefore furniſhed with exhaling Arteries, paſſing through its Subſtance ſo as to communicate with the external Air, as is evident not only from the tranſuding of Water through theſe Veſſels like Dew when injected; nor is this repugnant to the Aſſertion of *Ruyſch*, when he ſays, that neither the Corpus Reticulare nor Cuticle are furniſhed with any Veſſels; for he means, that they have no Veſſels capable of receiving any coloured Injection. The Moiſture which this way exhales, is the perſpirable Matter of *Sanctorius*. I have entertained ſome Thoughts that the perſpirable Veſſels of *Sanctorius*, might be the extreme Openings of the ſubcutaneous Nerves, ſince they are much leſs than the Veſſels which diſcharge the Sweat. But even if the Diameter of a ſmaller Veſſel be dilated, it may tranſmit a groſſer Humour in a larger Quantity, which we call Sweat; and even ſometimes Humours ſtill groſſer than that of Sweat, have been obſerved to paſs through theſe Veſſels. There was a Woman at *Amſterdam*, mentioned by *Ruyſch*, whoſe Menſes being ſuppreſſed at the uſual Paſſages, were diſcharged by Sweating through the whole Skin of the Body. But the Skin has yet another Office by its Nerves being diſpoſed in the

Form of ſenſible Papillæ, to guard and give notice by the Senſe of Touch of any Danger that might be threaten'd to the Body, while the other Senſes are not affected, as in Sleep. It is a Piece of great Providence in the Creator, that he has given Pain to Man as a perpetual and infallible Judge whether any Object is either amicable or offenſive to the Body, which is by this Senſe revealed to the Mind. But that theſe Papillæ may be kept ſenſible and apt to make a true Report, it is neceſſary for them to be perpetually moiſtened with an oily and aqueous Humour that they may not become callous, nor degenerate into Hair or Nails; for a Papilla when dry is inſenſible. The Tongue itſelf when it is become dry with a Fever, or by ſleeping with the Mouth open of a Morning, is not capable of diſtinguiſhing Taſtes. This is therefore one principal Uſe of the perſpiring Moiſture, namely, to keep the pulpy Extremities of the Nerves moiſt and ſoft; for when the Skin is deprived of this Moiſture, the Senſe of Touch is alſo depraved or aboliſhed. Beſides this the Skin is rendered ſoft and flexible by theſe Vapours. Mathematicians demonſtrate that when a ſtrait Cylinder is inflected, the Extremities are much extended; and therefore the Skin which cloaths the Articulations ought to be more flexible than the reſt, as we ſee it is, not only by the perſpirable Moiſture but alſo by the oily or ſebaceous Matter, which is moſt plentifully ſupplied to thoſe Parts.

[2] If theſe ſmall perſpiring Veſſels are diſſolved by a Bliſter or any cauſtic Medicine, their Humour is then collected under the Cuticle in the Form of a ſharp Water or Ichor, raiſing the Cuticle into a little Bliſter.

§. 421.

§. 421. There are alſo beſides theſe Arteries, the ſubcutaneous *Veins* [1], being diſtributed as before (§. 402.), *i. e.* ſmall Veſſels opening externally and terminating in the Veins, whoſe Office being not to exhale any thing, is therefore to receive or *abſorb* [2] any Liquor or Moiſture which inſinuates from without, and to convey the ſame together, firſt into the very thinneſt Lymph, and from thence by degrees to the thicker Lymph, paſſing afterwards to the Serum, and at length into the *Blood* [3] itſelf, with which it mixes; and the Truth of this we are convinced of from many and certain Experiments.

[1] The Arteries are always accompanied with Veins throughout every Part of the Body: and even a happy Injection of the Skin itſelf demonſtrates ſmall Veins which are not furniſhed with Valves.

[2] This Inſpiration of Moiſture is demonſtrated by many Experiments. Even *Hippocrates* has pronounced the whole human Body in Health, to be perſpirable as well inwards as outwards. Even *Paracelſus* writes, that as the whole Body ſweats from the internal Parts outwards, ſo, on the other hand, there is a ready Paſſage from without inwards through the whole Surface of the Skin. From hence we may conclude, that *Paracelſus* was not altogether ſo unworthy of the Character of a Phyſician and a Profeſſor, as is commonly ſaid and thought, unleſs you make a Skill in the Purity of *Latin* an eſſential Qualification in a Phyſician. He likewiſe adds an Experiment, for ſays he, I have nouriſhed Men for ſeveral Days together by apply-

ing nutritious Liquors to the naked Surface of the Body, (See §. 87. N°. 12.). The Moderns have furniſhed us with other Experiments. It is well known that Cantharides being externally applied to the Skin excites a Fever. *Bellini* took off a Portion of the Skin of the dead Body of a Man who died in Health, and ſewed it into a Bag in ſuch a Manner, that the external Surface of the Skin made the Inſide of the Bag, and filling it with warm Water, he hung it up in the Air, and obſerved that the Water ſweated through it. Mr. *Boyle* has furniſhed us with ſeveral other Experiments in his Treatiſes concerning the wonderful Subtlety of Effluvia, and concerning the Poroſity of animal Bodies. There is therefore a free Paſſage through the Skin, Cuticle, and reticular Body of *Malpighi*, by which watery Liquors may exhale, and be alſo again abſorbed by their reſpective Veins, in order to return through the large ſubcutaneous Veins into the Blood.

3 For the Blood would certainly be dried up by the continual Exhalation of Moiſture, which is made every Hour of Life, unleſs there was to be ſome return made of the Moiſture by theſe abſorbing Veins.

§. 422. But beſides theſe exhaling and inhaling Veſſels, there are *larger* 1 Openings or Ducts throughout the external Surface of the Skin, which diſcharge or exhale an *unctuous* 2 and *oily* 3 Subſtance, to relax, ſoften, and moiſten the Skin, as well as to preſerve its Warmth, and to prevent too great a Diſſipation. There are ſtill a good many other deep cylindrical and perpendicular Ducts, much larger than the former, on the Inſides of which open abundance of exhaling Orifices, whoſe Humour being dried up, forms a Paſte which turns black towards the Air, and may be preſſed out of the Skin in the Form of a little *Maggot* or *Worm* [4]; and this proves the Cauſe of many cutaneous Diſorders.

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[1] Theſe Cells are ſometimes ſo much enlarged in a healthy Perſon, that they reſemble Muſtard Seeds. *Ruyſch* was for many Years not well acquainted with the Nature of theſe Pores, as he writes in an Epiſtle to me, in which he imagines them to be mere excretory Ducts continued from the adipoſe Cells. But they are in reality lenticular Cells, in which an Oil is depoſited from many ſmall Ducts, where being retained and thickened, it is upon a proper Occaſion diſcharged by cylindrical Ducts, which perforate the reticular Body and Cuticle. It is in theſe Follicles that the Leproſy, Itch, and other cutaneous Diſorders are chiefly ſeated.

[2] All the Functions of the Skin depend upon its being ſoft and pliable, without which it becomes inſenſible, ſplits in the Hand, Lips, and other Parts, eſpecially when the intenſe Cold of the Winter has contracted the oily or ſebaceous Ducts in ſuch a Manner that they cannot diſcharge their Contents. The Skin therefore ſtands in need of being continually ſupplied with an Oil, and for that Reaſon it is perforated at ſmall Intervals with Oil-Ducts or Cells, that by the continual Warmth and Motion of the Parts, the Oil which is melted down may anoint and mollify the adjacent Skin.

[3] If you preſs the Hand hard againſt a Looking-glaſs, there will be little Spots, even though the Hand was waſhed clean: and if the Face is rubbed

with black Velvet it will appear white with the Oil that is taken off from the Skin. When I paid a Viſit to *Lewenhoec*, he took a very clean Piece of Glaſs, and preſſing it cloſe to the Skin, it appeared to be rendered foul, and upon examining the Matter with a Microſcope, it was found to be Drops of pure Oil adhering to the Glaſs. I afterwards undertook a more accurate Experiment of this Nature, for after waſhing my Face clean with Soap, upon preſſing the Cheek or Noſe before a Looking-glaſs, a white, thick, and oily Matter was forced out in the Form of a little Worm, which weighed near one Grain, being of the ſame Diameter with the ſecerning Follicle; but upon continuing the Preſſure longer, a true Oil came out. Such Follicles or Cells are ſeated in all Parts of the Skin, but they abound particularly in the Face, becauſe that is much expoſed to the Injuries of the Air and Weather; they are likewiſe ſeated among the Hairs, as in the Chin, Pubes, Scrotum, Arm-pits, and Anus; but the contained Matter frequently appears black from being corrupted or too long confined.

4 There are many Men who have their Skin foul and diſcoloured, or of a blewiſh caſt, from this Matter being accumulated and condenſed. But although this Matter is diſcharged in the Form of a Maggot by Preſſure, yet it is not really ſo, as many have miſtakenly imagined, though it muſt not be denied that ſometimes real Inſects are bred in the Follicles of this Matter under the Skin, as is frequently obſerved in *Aſia*; and the Sirons, as they are called, dwell in theſe Cells when they cauſe the Itch, and Lice make their Neſts there, in the Pthiriaſis of which Diſtemper great Princes have been known to periſh.

§. 423. Over all theſe is extended the *Cuticle*[1] or ſcarfy Skin, which by Reaſon of the Minuteneſs of its Veſſels and connecting Fibres, may be eaſily broke by the leaſt Force ſo as to be entirely ſeparated from the ſubjacent Parts. It is diviſible into ſeveral Lamellæ or Scales, containing no Veſſels which can be rendered viſible by any Artifice; nor is it at all ſenſible, but is compoſed altogether of ſmall *Scales*[2] which are again diviſible into ſmaller, 'till they come to an incredible Minuteneſs, and being cut or marked out into *Furrows*[3] and Ridges, it appears to be diſpoſed in ſpiral Rows, which are moſt conſpicuous in the Ends of the *Fingers*[4]; and in the middle of the Furrows betwixt theſe Ridges, the ſudoriferous Veſſels are Pores, have a ſafe Outlet, on each Side of which and placed Rows of nervous Papillæ parallel to the former. From whence it is evident that the ſudoriferous and exhaling Veſſels, with the Papillæ for the Senſe of Feeling, are *defended*[5] with this thin Covering without impeding or *augmenting*[6] the Senſe of Touch.

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[1] The Structure of the Cuticle is indeed wonderful in many Reſpects. When a Portion of the Skin taken from a dead Body, has been macerated a long time in warm Water, it almoſt entirely diſſolves, and leaves only the Cuticle with the Hairs and Nails remaining; even in Putrefactions of the Skin, Inflammations or Gangrenes, the Cuticle is only elevated from the Skin without at all being corrupted. And in theſe Diſorders likewiſe

wiſe the Nails are very eaſily ſeparated from the Parts to which they adhere. But the Cuticle is perforated with an infinite Number of Pores, inſomuch that *Lewenhoec* computes that 125000 of them open within the Compaſs of a Grain of Sand: but if this Computation is by much too large, yet we are certain that the Number of theſe Pores is very great. Theſe Ducts or Pores ſeem to be of the arterial kind, ſince they continually exhale the perſpirable Matter; but there are as many inhaling Veins (§. 241.) interſperſed through the Skin as there are exhaling Arteries, diſcharging the perſpirable Matter of *Sanctorius.* Beſides this, the Cuticle is perforated with many larger Ducts which diſcharge the Sweat, together with the Orifices of the Cells containing the ſebaceous or oily Matter, which by Preſſure is diſcharged in the Form of a Vermicle (§. 422.), all which are conſpicuous by the Microſcope. The Cuticle alſo gives an external Caſe or Covering to the Hairs, and defends the nervous Papillæ; it is not therefore one continued or ſolid Membrane, but is perforated with many ſmall Holes like a Net or Strainer. In the Blackmoor the Cuticle is found to be very white, the Blackneſs ariſing from the reticular Body which is placed underneath.

² It is not the fæcal Part of any of the Humours which are diſcharged through the Skin, nor is it the glutinous Part of the Humours dried up over the Skin; but it is compoſed of an infinite Number of exhaling and inhaling Veſſels, connected to each other by Scales, which are by degrees hardened and compacted together by the Air and the Contact of external Bodies, becoming callous by Attrition, in ſuch a Manner that the intermediate Spaces or Rings are much harder

than the reſt of the Cuticle. From hence we may underſtand the Reaſon why the Cuticle is ſo eaſily ſeparable from the Skin: namely, 1. Every Vaſcule is as ſmall again at its Extremity in the Cuticle, and its Coheſion is there not half ſo ſtrong, whence it may be ſeparated or broke with half the Force. 2. As all the Extremities of theſe Veſſels cohere together, they muſt neceſſarily ſeparate all together.

[3] Theſe ariſe partly from the Motion of the ſubjacent Muſcles, and partly from the Diſpoſition of the nervous Papillæ. Under the Nails they are diſpoſed longitudinally, according to the Length of the Finger; in moſt Parts of the Body they are rhomboidal, but in the Ends of the Fingers they are diſpoſed in a ſpiral Order. It is the regular Order of theſe Papillæ, for the ſake of which the Cuticle is thus diſpoſed in the Ends of the Fingers. This was truly obſerved by *Malpighi*, namely, that the ſenſible Papillæ lie concealed in the Sulci formed by the Cuticle; but if the Sides of the Sulci open the exhaling Veſſels which diſcharge the Matter of Sweat, as may be eaſily ſeen by the naked Eye in a clean ſoft Hand, it is apt to ſweat in the Summer Time; and they appear ſtill more conſpicuous in the Palms of the Hands and Soles of the Feet. To theſe Sulci of the Cuticle the reticular Body very firmly adheres; and hence it is that when the Cuticle is abraded, the Corpus Reticulare comes off along with it; and from hence alſo we may underſtand the Reaſon of the intenſe Pain, which follows when a Gangrene invades theſe Parts.

[4] The Cuticle adheres to and is continuous with the Nails; for the nervous Papillæ which are ſeated at the Ends of the Fingers, becoming

hard or callous, compoſe the long Filaments of the Nail, which we ſee by a Microſcope continued in right Lines cloſe to each other: but the Cuticle inſinuates itſelf partly underneath, and at the Ends of the Fingers it is reflected back under the Nail, after forming the wonderful Sulci beforementioned; ſo that the Cuticle is extended both under and over the Subſtance of the Nail. But immediately under the Nail itſelf, the nervous Papillæ are naked, without being defended by any Cuticle of their own.

[5] This is one of the principal Uſes of the Cuticle. The cutaneous Nerves are very ſoft, and like a Pulp; but by their Contact with the external Objects, they eaſily depoſit their Senſibility, and become hard or callous, as very frequently happens in the Palms of the Hands and Soles of the Feet of thoſe People who are addicted to Agriculture, or to any other kind of laborious Exerciſe. Beſides this, we even obſerve that the nervous Papillæ have a natural Inclination to degenerate from their own Nature, into that callous and inſenſible Subſtance which forms the Hair and Nails; betwixt which there is little or no Difference, except that in the Nails the Filaments which would have formed Hairs are cemented cloſe to each other. *Du Verney* has demonſtrated, that the cutaneous Papillæ of an Elephant are continued from its Snout, almoſt like Snails Horns, in which the Eyes of that Reptile are fixed. We likewiſe obſerve the ſame Productions of the Papillæ in the Snout of a Hog, and in the human Tongue; and if we apply a Bit of Sugar to the Surface of the Tongue before a Looking-glaſs, we ſhall obſerve that the Papillæ extend or raiſe themſelves up towards the ſaid Body. Therefore the Cuticle defends the Papillæ from being dried or

injured by the Air, or any other external Bodies, by covering them as with ſo many Caps. But beſides this, the Cuticle has many other inferior Uſes.

[6] We obſerve that the Cuticle renews itſelf after it has been abraded: and this it always does, provided the reticular Body of *Malpighi* is not deſtroyed; as, for Inſtance, when the Cuticle is raiſed and taken off by bliſtering with Cantharides. But if the reticular Body of *Malpighi* is deſtroyed, in that Caſe a Cicatrix or imperſpirable Cruſt is formed, inſtead of the Cuticle. Finally, the Cuticle inveſts the whole external Skin; but yet it does not terminate where the ancient Anatomiſts have fixed the Termination of the Skin, as in the Lips, Eyebrows, *&c.* for the Cuticle is ſtill continued with little or no Variation of its Texture, and paſſes under the Denomination of Epithelium, ſo called by *Ruyſch*; and thus the Cuticle lines all the internal Cavities of the Mouth, Ears, Oeſophagus, Stomach and Inteſtines; whence the Surface of this Integument appears to be much larger than is commoly ſuppoſed.

* * *

Of the SWEAT.

§. 424. THE Sweat is diſcharged out of open Orifices ariſing from under the Scarf-Skin, and paſſing through Perforations in the reticular Body by excretory Veſſels, which are ſent out from a ſort of glandular Bodies, commonly called *Glandulæ Miliares*[1], which lie upon the Fat, and are diſperſed throughout the whole Body, being furniſhed each with an Artery, Vein, and Nerve, as well as with an excretory Duct, which, as we ſaid before, perforates the reticular Body (§. 418.), and diſcharges the Sweat by an open Orifice in the Cuticle (§. 423.), which Orifice ſeems to be covered with a hollow *Valve* [2] capable of being elevated, and placed in ſuch a manner under the Scales of the Cuticle, that it can either tranſmit or confine the Humours. And this is the principal Organ of the groſs Sweat; to which add the other ſmaller Veſſels of *Ruyſch* [3], which do not ſo nearly approach the Fabric of a Gland, but uſually diſcharge a *more thin* [4] or watery Sweat (§. 420).

[1] *Ruyſch* does not admit of any miliary Glands, but it is no difficult Matter to demonſtrate them: for if the Arm of a healthy Perſon be expoſed to the cold Air, the Skin immediately ariſes up into an infinite Number of ſmall Tubercles, inſomuch that the whole Arm appears rough like the Skin of a Gooſe, all which Tubercles again diſappear ſo ſoon as the Warmth of the Arm is reſtored either by Friction or by returning the Clothes; they even vaniſh of themſelves after a while, if the Arm is continued longer in the Cold. But what can be more natural and plain than for us to conclude from hence, that the Cells or Follicles in the Skin, are full of Matter to be diſcharged through the Cuticle, and that when the Humour continues to be ſecerned while it cannot be diſcharged, by reaſon of a Conſtriction in the Pores by Cold, it therefore diſtends the Follicles by its Retention. But the ſame Tubercles diſappear after

ter the Cold has continued ſome time, ſo as to penetrate into the Skin itſelf, and contract the Follicles by evacuating their Contents; and they alſo diſappear by Warmth or Friction, when the Pores are opened ſo as to evacuate their Contents: it is therefore manifeſt that they muſt be a ſort of Machines capable of expanding and contracting, and that they contain a particular Humour of their own. But it is no matter whether we call them miliary Glands with *Malpighi*, or ſimple Follicles or Drains according to *Ruyſch*. I have even obſerved the Nature of theſe Follicles in ſeveral Parts of the Body, ſo as to obtain a better Idea of them than *Ruyſch* himſelf who prepared the Parts: I diſtinguiſhed ſmall Arteries and Veins which were ſpent upon the Membrane of each Crypta or Cell, the Cavity of which terminated in a much narrower Duct; the Neceſſity of which Mechaniſm is demonſtrable from the Nature of the Secretion itſelf. *Ruyſch* makes theſe Emiſſaries to be the Extremities of the ſudoriferous Veſſels themſelves; whereas there is not the leaſt room to doubt but that they are real Cryptæ, which not only contain a thin Humour, but alſo retain the ſame for ſome time, ſo as to render it thicker before it is diſcharged. There are many of theſe in the Face, Lips, and Corners of the Mouth, as alſo in every Part of the Body, which has any Motion or Attrition over another; but this unctuous Humour which is required for preventing the Attrition of all Parts of the Skin, muſt be ſupplied from ſmall Glands.

[2] The open Orifices of all the cutaneous Follicles, and the Mouths of the exhaling Arteries, are each of them furniſhed with a ſort of Valve or Stopper, the Nature of which was firſt diſcovered from an Examination of them in brute Animals. *Du Verney* obſerved that in the Cuticle of an Elephant,

phant, each exhaling Veſſel was furniſhed with a Cap or Cone, like thoſe of Sugar-bakers, which was moveable ſo as to give the exhaling Humours a free Paſſage into the Air. It is indeed true that in the human Body we find no ſuch Machines as theſe, but there are Scales which fold over the Mouths of the exhaling Veſſels, and perform the ſame Office, that is to ſay, the exhaling Arteries open obliquely under the Scales of the Cuticle. After the Feet have been well waſhed and cleanſed, if you wear a Pair of black Stockings, you will ſee continually that a white Matter adheres to them from the Skin, which being viewed by the Microſcope appears to conſiſt of mere Scales. Theſe Scales being eaſily rubbed off, are as ſpeedily renewed again; but their Office is to cover the Mouths of the cutaneous Pores, ſo as to moderate the Diſcharge of their Humours, and prevent any groſs Matter from entering from the Air without, ſo as to obſtruct the Humours, and render them impervious.

[3] If the Cuticle be removed, and a ceraccous Injection thrown into the Arteries, it will tranſude through the Membranes of the Noſe, and be diſcharged almoſt like the Mucus which covers that Membrane. Even after mature Conſideration, I muſt confeſs that much the greater Part of that Humour which we call Sweat is diſcharged by Veſſels continued directly from the Arteries, and that the Quantity of Sweat which comes from the Follicles is much leſs.

[4] The Sweat is a watery Liquor, but much thicker than Water itſelf, coming from the exhaling Arteries of *Ruyſch* in the Skin, and diſcharged by Emiſſaries belonging to the Plexus of ſubcutaneous Veſſels. When a Perſon is hot either by voluntary Exerciſe or by a Fever, he

diſcharges a yellow Sweat which ſtains the Clothes with Spots; and this follows, becauſe the Force urging the Humours outwards is ſo great as to propel groſſer Parts of the Fluids than are naturally uſed to paſs that way; and at the ſame time the Cells receiving the Sweat and Oil are waſhed out and diſcharged of their thicker Contents, at the ſame time alſo the exhaling Veſſels are ſo dilated as ſometimes in great Agonies and violent Heats to diſcharge even the Blood itſelf, which ruſhes forth by theſe Paſſages; a notable Inſtance of which we have in our Saviour. I ſaw a Woman at *Amſterdam* who diſcharged her menſtruous Blood through the Pores of the Skin in the Head; and the ſame Spectacle was viewed by many curious and learned Perſons: and we have an Account of an *Iriſh* Nobleman in the *Philoſophical Tranſactions*, (N°. 171.), who had a periodical Diſcharge of red Blood from the Extremity of his little Finger.

§. 425. The Sweat thus ſeparated and diſcharged is various in its Nature, according to the Variety of *Weather* [1], the Soil or *Country* [2], the Sex, Age, and Habit of the Patient, and the *Parts* [3] or Emunctories themſelves, with the *Diet* [4], Courſe of Life, and the time of its *Concoction* [5], almoſt in the ſame manner as we obſerved of the Urine (§. 368. & *ſeq.*)

But Sweat is hardly ever found in a healthy Body, unleſs ſome Exceſs or *Error* [6] has been committed in the ſix Non-naturals. The firſt immediate Effect of Sweat is always *prejudicial* [7], but by Accident it is ſometimes *ſerviceable* [8].

The

[1] The hotter the Country the more fœtid is the Sweat and even the Difference is very conſiderable betwixt the Sweat of the Winter and that of the Summer-time.

[2] As Countries differ ſo does alſo the Sweat both in its Quantity and Quality: for the Nature of the Sweat in *Europeans* is very different from that of the *American* Inhabitants.

In general the Sweat of Men is more acrid and ſmells ſtronger than that of the female Sex.

[3] The Sweat of the Head is more oily and emplaſtic, that it may diſtil along the Hairs, and equally anoint them that they may not ſplit by being too dry. The Nature of the Sweat which exhales from the Armpits is very different from that which is diſcharged from the Feet; and this Difference is very perceptible both in the Smell and Taſte. In the Feet the Sweat turns to thick Fœces, while in the reſt of the Body it forms a kind of Liniment like Soap. That the cutaneous Diſcharge is very different in its Nature, we are taught by the Criſes of Diſeaſes. If a Bubo ariſes in the Peſtilence, either under the Arms, Ears, or in the Groins, it is uſually ſalutary, whereas it is of no Service in any other Part of the Body.

[4] There have been ſome Men known to diſcharge an acid Sweat, while others exhale a putrid and fœtid Vapour. The *Laplanders* who live upon Fiſh, have their whole Skin ſmelling like a fœtid Pickle or Brine of Fiſh, much like the Oil of Whales, which is called Blubber. Thoſe who eat Onions and Garlick carry the Scent of their Food in their Sweat. And in general the more the Body is exerciſed, the more acrid are the Salts, and the more ſubtle the Oils which compoſe the Sweat, and the Scent and Smell is alſo proportionably more fœtid.

[5] The Sweat differs in every Degree of the Concoction of the Aliments. There is a Sweat from the Drink, a Sweat from the Chyle, and another kind of Sweat from the Serum of the Blood; and even urinous Sweats happen in thoſe who are afflicted with an Iſchuria (§. 384). For there is a near Reſemblance betwixt the Matter of the Sweat and Urine; and the Sweat being increaſed, the Diſcharge of Urine is diminiſhed, and the Reverſe; for if there is a great Diſcharge by Urine, no Sweat can be expected.

[6] A Perſon in Health will not ſweat, unleſs he is too much heated by Exerciſe, or by too plentiful a Uſe of Spices, *&c.* if moreover there is no thin Liquor drank at that time, the Sweat will then be more yellow, fœtid, and thick. But the Reaſon why a healthy Perſon does not ſweat, conſiſts in the Smalneſs of the ſudoriferous Veſſels, which do not tranſmit ſuch groſs Particles, unleſs they are urged or dilated by the Impulſe or increaſed Motion of the Humours behind, or unleſs the Blood itſelf is more diſſolved than uſual, as it happens in ſome Diſeaſes; or laſtly, unleſs the ſudoriferous Veſſels themſelves are too much relaxed, as remarkably happens in fainting Fits. It is an Obſervation of the Ancients, that the Body falls away by too profuſe Sweats. In exerciſing the Body, it ought to be taken for a Rule to leave off as ſoon as ever a Sweat appears.

[7] For it always denotes, that there is ſome preternatural Condition of the Blood in the Body.

[8] *Hippocrates* of old has pronounced, that the Seat of a Diſeaſe is in that Part which ſweats. Yet a Sweat may be of Service by Accident, becauſe it demonſtrates that the Skin, which was before obſtructed, is now open and pervious; and alſo that a conſiderable Portion of the noxious Humours

are diſcharged in the Sweat. Many acute Diſeaſes go off in critical Sweats. For ſo long as the inflammatory Diſpoſition of the Blood continues, ſo long will the Skin be dry, and no Sweat can be ſeparated, becauſe of the Thickneſs of the Humours: but when a Sweat appears, it demonſtrates that the Veſſels are relaxed, and that the morbifick Matter is attenuated, whence we may reaſonably hope that the Diſeaſe will be happily terminated in Health. But ſuch a critical Sweat is uſually very thick and fœtid. *Sydenham* has made it an Obſervation in the Plague, that thoſe Patients recovered, who towards the End of the Diſeaſe continually diſcharged a viſcid Sweat for twenty-four Hours ſucceſſively: and thus alſo a Sweat following the Bite of venomous Animals is good, inaſmuch as it evacuates the Particles which were conveyed into the Blood.

Of the Sanctorian *Perſpiration.*

§. 426. BESIDES the afore-mentioned ſudoriferous Veſſels, there are other exhaling Veſſels ſtill ſmaller, which open obliquely under the ſmall *Scales* [1] of the Cuticle, and which are of that Subtilty, that *Lewenhoec* computes that 125000 [2] of them open in the Space of a ſingle Grain of Sand; and through theſe is perpetually tranſpired a very ſubtle Humour from every *Point* [3] of the Body, called from its Inventor the *Sanctorian Perſpiration*, who not only firſt diſcovered, but has alſo the Glory of compleating this material Doctrine of the perſpirable Matter.

[1] But theſe ſmall Scales are the Extremities of the excretory Ducts inflected over the Mouths of the exhaling Veſſels.

[2] When *Lewenhoec* by his Glaſſes, which ſurpriſingly magnified the ſmalleſt Bodies, could not clearly diſcern theſe ſmall perſpiring Veſſels, he concluded by deducing an Eſtimate from thence, that 125000 of theſe Veſſels opened within the Compaſs of a ſingle Grain of Sand.

[3] If the Hand be inſerted into a Heap of Ice, which has been preſerved under Ground in the Summer time, it will ſmoke or fume in a manner as if it was on Fire. But ſuch a Fume or Vapour is continually exhaled out of the Body; nor is it produced by Cold, only being before inviſible, it is by the Cold ſo much condenſed as to be conſpicuous to the naked Eye: thus the Breath in Summer time is not perceptible as it paſſes out of the Lungs, but by the Winter's Cold it is ſo much condenſed as to appear like Smoke. If an intenſe Cold could be ſuddenly produced in a cloſe Chamber full of Company, one Perſon would not be capable of ſeeing another through the Fog or Vapours which exhale from their own Bodies, almoſt in the ſame manner as the Poets feign the Gods to be hid each in their proper Cloud. In *India* the Heat is perpetual, nor can a Perſon's Breath or perſpirable Vapours be there at any time ſeen; inſomuch that when the *Indians* are brought into the colder Climates of the frigid Zone, they are ſurpriſed to ſee a kind of Smoke evacuating by their Mouths, as if a Fire was contained within them. If a Piece of gold Coin that has been well poliſhed and cleaned, is made very cold, as it may even in Summer, by

dipping in an artificial Mixture of Sal Ammoniacum and Water, upon applying it afterwards to any Part of the Body, it will be obſcured by the perſpiring Vapours. If the Arm is inſerted into a glaſs Receiver, the exhaling Vapours will be condenſed into Drops hanging upon the Sides of the Glaſs; it is therefore certain, that a moiſt Vapour continually exhales from the Surface of the Body. And theſe Vapours flying off in an inviſible State, are called the perſpirable Matter of *Sanctorius*; but when the ſmall Particles of theſe Vapours are diſcharged ſo near each other, as to come into Contact, and form little Drops, we then give them the Denomination of Sweat. But as there are exhaling Veſſels opening throughout every Point of the Cuticle; ſo likewiſe, agreeable to the Courſe of Nature, there muſt conſequently be ſmall inhaling Veſſels correſponding to the former. But both theſe Kinds of Veſſels were very well known to *Hippocrates*, who includes both Kinds of Perſpiration, exhaling and inhaling, in a very few Words, when he tells us, "That all the Parts of the Body "perſpire from within outwards, and from without "inwards." But he has likewiſe obſerved, that there are Cavities in the Body, which in a healthy State are filled with Spirits, but in a diſeaſed State they are filled with Ichor. By Spirits he underſtands an inſenſible Body, which yet produces a conſiderable Effect; and by Ichor he intends the ſame inſenſible Spirits condenſed into a viſible Humour. After *Hippocrates*, *Galen* has left us ſeveral material Paſſages concerning the Perſpiration. But the firſt who made any Eſtimate of this conſiderable Diſcharge was *Sanctorius*, an Author entirely addicted to *Galen*, and who with incredible Labour, and innumerable Obſervations made during the Space of thirty Years, compiled together the moſt material

Part of the Doctrine into a ſmall Book of a few Pages, reducing the particular Experiments into a few univerſal or general Rules, admitting of no Exceptions. I muſt in ſhort confeſs, that theſe Aphoriſms of *Sanctorius*, with thoſe of *Hippocrates*, are Writings of greater Merit than any other in the whole Art of Phyſic; and even if we compare the Merits of theſe two together, the Preference will perhaps be readily given to *Sanctorius*.

§. 427. This Exhalation ariſes from the *whole* [1] external Cuticle, as alſo from the Cuticle of the Mouth, Noſe, Fauces, Larynx, Lungs, Oeſophagus, Stomach, Inteſtines, Bladder, and Uterus; ſo that the Quantity of it *exceeds* [2] the aggregate Quantity of all the other Fœces together: for in *Italy* a Perſon who is ſtrong or middle aged, lives regularly, and uſes a moderate Diet, diſcharges as many Vapours from the external Skin, Mouth and Noſtrils, as is equal to five Eighths of what was taken into the *Body* [3].

[1] The whole Surface of the human Body, without excepting any Part, is perſpirable, except a Cicatrix ſhould be any where formed by a Conſumption of the adipoſe Membrane, or a Calloſity in any Part of the Cuticle. But the Scarf-Skin is extended or continued much beyond the Skin itſelf, which terminates at the Tarſus or cartilaginous Edge of the Eye-lid; whereas the Cuticle is inflected under the Eye-lid to the Bulb of the Eye itſelf. The Skin itſelf is hardly continued above the tenth of an Inch within the Noſe, terminating ſuddenly as if it was cut off, while the Cuticle ſtill continues all over the internal Surface of the Noſe,

We ſee that the Skin terminates abruptly in the Lips, in a manner as if it was cut of; but the Cuticle itſelf enters the Mouth and covers the Cheeks and Gums; then again it becomes thicker upon the Tongue, almoſt as it appears in the Hands and Feet, and then it goes on to cover the Inſide of the Trachea and Lungs, with the Oeſophagus, Stomach, and Inteſtines. Perſpiration is therefore made as well from the internal Surface of the Noſe, Mouth, and eſpecially the Lungs, which laſt Exhalation is by *Sanctorius* computed to be one ſixth Part of the whole Perſpiration; having perhaps made the Experiment by condenſing his Breath in a Glaſs. In extreme cold Weather by blowing my Breath againſt a Glaſs, it has been inſtantly covered with watry Drops, which in a ſmall Space of Time have been converted into Ice; and by this means one may weigh the Moiſture of the Breath, provided we can have the Opportunity of Cold whenever we pleaſe. But wherever there is a Cavity in the Body; there is Perſpiration carried on. Even a thin Liquor exhales into the ſeminal Veſicles as well as into the urinary Bladder. If the Moiſture be wiped off from the Pleura, it grows moiſt again, and if you wipe it dry a ſecond time, the Humidity will even ſtill return; but then this internal Perſpiration is not evacuated from the Body, but abſorbed through the Veins deſtined to that Office.

[a] If you ſhould be ſurpriſed that an inviſible Vapour ſhould carry off ſo large a Quantity in proportion to what is evacuated by the other Emunctories, you need only reflect and conſider upon thoſe Vapours which float in the Air, and are collected together about the Tops of the Mountains, ſo as to produce the vaſt Quantities of Water, which appear to us in the Form of

ſmall Rivers, or Springs, and great Showers of Rain.

[3] *Sanctorius* ſpent thirty Years in making Experiments, the infinite Number of which he reduced to a few Obſervations and general Rules. He found that the Weight of his Body, for Example, was at one Day 120 Pounds, and the next Day at the ſame Hour it was alſo 120 Pounds: but then the Urine and the inteſtinal Fæces weighed almoſt three Pounds, while the Aliments both ſolid and fluid taken into the Body, weighed eight Pounds; from whence he concluded, that as no Addition was made to the Weight of the Body, the other five Pounds of the ingeſted Aliments muſt have paſſed off by ſome unknown Courſe; inſomuch that of eight Pounds of Meat and Drink, only four Ounces was evacuated by Stool, ſixteen by Urine, and twenty-four at leaſt exhaled by inſenſible Perſpiration.

§. 428. The great *Subtlety* [1] of theſe Vapours, and the *equable* [2] or uninterrupted Manner in which they are continually and very *copiouſly* [3] diſcharged, with the Senſe of *Lightneſs* [4] which they produce in the Body, the Weight of which is *increaſed* [5] by the Balance without any Senſe of Heavineſs after *Sleep* [6], demonſtrates the Perſon to be in the moſt perfect Health, and is alſo one of the principal Means of *preſerving* [7] Health.

[1] The moſt healthy Perſon who commits no Error in his Diet, nor in any of the ſix Non-naturals, will not evacuate any ſenſible Sweat, but nevertheleſs he will be five Pounds lighter in the Space of twenty-four Hours by the Exhalation of this inviſible Vapour. But the Cold of the exter-

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nal Air cannot but conſtringe the cutaneous exhaling Pores, ſo as to reduce the Mouths of each to a ſmaller Diameter than they naturally had before; and this is evident from the common Experiment by which the ſame Pores being quite cloſed by extreme Cold, the retained Vapours elevate the Cuticle into ſmall Tubercles. In the mean time what *Hippocrates* has pronounced is certainly true, namely, that in the Winter and Spring the Viſcera are warmer, and digeſt more powerfully; ſince at thoſe times we eat more and ſleep better. But theſe Obſervations demonſtrate that in Winter and Spring, the ingeſted Aliments are more eaſily concocted and evacuated in very thin perſpirable Vapours; but Health is always the more perfect as this perſpirable Matter is more ſubtilized; and it may eaſily appear, that no ſmall Force is required to be capable of attenuating Beef, for Inſtance, ſo as to exhale or flie off in volatile Vapours. Therefore the ſmaller the Pores the more perfect is the Perſpiration, ſince they only exhale the moſt ſubtle Particles: and Perſpiration is always more plentiful in proportion as a larger Quantity of the Aliments are attenuated into perſpirable Matter by a healthy Perſon.

[2] For Perſpiration is not eaſily diſturbed by ſlight Cauſes, but continues regularly the ſame for a long time; the Effect of which is to conduce to long Life, provided the Weight of the Body always continues the ſame, whether the Perſon eats little or much: for the Perſon who daily finds his Body return to the ſame Weight for many Years, ſuch a one is diſpoſed to live long. Even this is a ſure Sign of a ſtrong and healthy Habit, ſince it ſuppoſes a conſtant Equality of all the Powers which together produce Health. Before any Diſeaſe the Perſpiration is always diſturbed, being

either diminiſhed, ſuppreſſed, or render'd ſenſible in the Form of Sweat, when it ought to have been inviſible; and then we perceive a Heavineſs in the Limbs. Waſting Bodies often become a whole Pound heavier within the Space of an Hour. If you reſtore the Perſpiration to a gouty or dropſical Foot, you will have performed all that is neceſſary towards a Cure. Where-ever a Phlegmon is ſeated, no Perſpiration is there carried on. In all acute Diſeaſes, a Regard muſt be had to the Tongue and Eyes: for if the Tongue appears covered with Mucus, and the Eyes look red, it is a certain Sign that the Perſpiration is diminiſhed throughout the whole Body.

3 Whatever is diſcharged of the Aliments by Perſpiration, can be neither crude nor half concocted, but muſt have paſſed through the ſeveral neceſſary Degrees of Attenuation, ſo as to exhale in the Form of Vapours; and therefore in general the Perſon is better in Health, as the Perſpiration is larger.

4 The Body ſeems light as to Senſe, whenever it perſpires equally; and this happens when all the Humours of the Body are duly circulated through their reſpective Veſſels. But that Part of the Body which perſpires leſs than the reſt, muſt be heavier; and if the whole Body does not perſpire, the Heavineſs will be continued throughout the whole. If the Perſpiration is frequently interrupted, and as often reſtored, then the Weight of the Body continually varies. A healthy Man weighing two hundred Pounds, does not perceive any thing of that Weight when he ſtands upon his Feet; but if he is afflicted with ſome Diſeaſe, he immediately feels a Heavineſs all over his Body, which he is ſcarce able to ſupport. For the Body ſeems light and inſenſible of its own Weight only, when all

the Humours are pervious, and move freely and equably through all the Series of decreaſing Veſſels, in ſuch a manner that all the Humours which are thinner than the Blood itſelf may be ſucceſſively derived from thence, and paſs readily into and through their reſpective Veſſels; and this demonſtrates that the Solids are moſt exquiſitely adapted to the Fluids, and the Fluids or Humours to their reſpective ſolid Veſſels.

[5] If a Perſon grows three Pounds heavier within the Space of a Year, and yet does not perceive any Impediment in the Exerciſe or Motion of the Parts, it is a manifeſt Sign that the Powers of Health are perfect and well regulated in ſuch a manner that they cannot deſtroy each other: and in general the Body appearing to be heavier by the Balance, and yet not heavier as to Senſe, is a ſure Sign of perfect Health; for ſuch a Perſon will neither ſweat nor diſcharge much either by Urine or Stool.

[6] If the Head appears free for exerciſing the Faculties of the Mind, it is a Sign that Sleep has had a good Effect by evacuating the redundant Humours in the Form of perſpirable Matter; but if the Head feels dull and heavy, it is a Sign that the Veſſels of the Brain are not duly pervious, and that the Perſpiration itſelf is not rightly performed, whence Diſeaſe muſt be the Conſequence.

[7] If a Phyſician knows how to retain the Perſpiration in an equable and juſt Degree, he knows the great Secret of curing all chronical and acute Diſeaſes. But ſince we are deſtitute of any ſuch Method, we muſt endeavour to reſtore or augment the Perſpiration in proportion to its Deficiency.

§. 429. But when this Diſcharge recedes from the afore-mentioned Conditions (§. 428), it is a moſt certain Sign, and almoſt the firſt Cauſe of *Diſeaſes* [1] in the Body.

[1] In thoſe Perſons who have a Fever, or a Pleuriſy invading, I have experienced in myſelf that the Body is dull or heavy for two or three Days before the Diſeaſe, being eaſily fatigued and out of Breath by the leaſt Motion or Exerciſe. Hence *Hippocrates* obſerves, that a ſpontaneous Laſſitude is a Sign or Forerunner of Diſeaſe: but this Laſſitude is alſo a Sign of a diminiſhed Perſpiration. If a Perſon perſpires leſs than uſual but for the Space of a Day, a Heavineſs or Laſſitude will be perceived. From hence we know when Perſpiration is impeded; by reſtoring which, we reſtore Health. But if through fatiguing Buſineſs, or any other Cauſe, you neglect this Evacuation, and inadvertently return to Labour, the whole Power of the Diſorder will then be returned upon the Body; from whence it can be never freed, but by reſtoring the Perſpiration. In ſhort, the Cure of a Pleuriſy, if we rightly conſider its Nature, conſiſts in reſtoring the Perviousneſs of the obſtructed Veſſels, and in rendering the groſs Humours ſufficiently fluid: both which Intentions are anſwered by procuring a free Perſpiration. Hence thoſe who have acute Fevers never ſweat nor perſpire in the Beginning of the Diſorder; but if a ſlight Moiſture breaks forth ſpontaneouſly through the Skin before the third Day of the Diſeaſe, the Patient is out of Danger, and the Perſpiration reſtored. Nor can Obſtructions of the ſmaller Veſſels be removed, unleſs the larger Veſſels are firſt rendered pervious. The Perſpiration is therefore a

ſure Sign both of the approach and going off of a Diſeaſe.

§. 430. This inſenſible Evacuation is *preſerved* [1], increaſed and reſtored by the Viſcera, Veſſels and Fibres being continued in full Strength; by *exerciſing* [2] the Body, until a *ſlight* [3] Sweat begins to appear; by a moderate Uſe of *Venery* [4] occaſioned or excited by the natural Strength of the healthy Body, and not by any Inſtigation or Advice of the Mind; by continuing the *Sleep* for ſeven or *eight* [5] Hours, with the Body well *covered* [6] *, but not oppreſſed with too great a Weight of *Bed-cloaths* [7]; by *affecting* [8] a moderate Degree of Chearfulneſs or Joy, by Youth, and the Uſe of light *ſolid* [9] Food, well *fermented* [10], and ſeaſoned with light Spices, avoiding every thing fat or oily in all Shapes; and laſtly, by a pure, calm, dry, heavy, and cold *Air* [11].

[1] All thoſe Parts of the Body which elaborate the crude Chyle, and make it paſs through all the Degrees of Attenuation, ſo as to paſs off at length in the State of inviſible Vapours or perſpirable Matter, are here intended: and therefore the Stomach, Inteſtines, Heart, Lungs, and all the Arteries, *&c.* are thoſe Parts, upon the Strength and healthy Diſpoſition of which depend the Formation of the Chyle, and ultimate Attenuation of it, in order to evacuate ſome Part of it by Perſpiration. But ſince the perſpirable Matter of *Sanctorius* is the ultimate and fineſt Excretion in the Body, ſuch a Degree of Health and Strength is required in all the Parts, as may be ſufficient to duly cir-

culate and attenuate the Juices. Hence *Hippocrates* obſerves, that the Viſcera are naturally ſtronger and warmer in the Winter and Spring; though *Helmont* oppoſes this Doctrine, and contends that the Venters are at that time colder: but he did not underſtand the Mind of *Hippocrates*; for the divine old Man intends that Nature generates more Warmth internally in the Winter. For ſince the external Air is at that time very cold, and continually takes off ſome Part of the Warmth of the human Body, and yet we ſee that ſo much Motion is produced by the vital Powers, as ſuffices to render the Perſon capable of all the Actions of Life, and at the ſame time to produce a conſiderable Atmoſphere round him much warmer than the Air; it is evident, that the Power of the arterial Syſtem muſt be at that time great, and capable of circulating the Humours through the Body with a ſufficient Degree of Motion. Hence it does not ſeem extraordinary or incredible, that the internal Part ſhould be warmer in Winter than in Summer: for there is no Effect produced by the Viſcera or Veſſels upon our Humours, except that which they make by Preſſure and Attrition; nor are the Viſcera any thing more than various Heaps or Aſſemblages of Veſſels, by the Efficacy of which the groſſer Humours are attenuated to a great Degree of Subtlety. And therefore a ſimple Contraction of the ſolid Fibres and Veſſels will be (*cæteris paribus*) the Cauſe of the moſt perfect Digeſtion of the Aliments. And therefore the Winter's Air with Froſt, free from Wind and Clouds, being calm and heavy, conſtringes the Fibres of the Body, and increaſes their Strength, by which a great Part of their Humours are elaborated into thin perſpirable Matter: and therefore in the ſharpeſt Winter we are healthy, ſtrong, very hungry, and perſpire more largely. But the Ancients erred in thinking that a ſerene Air was the lighteſt.

[2] Our Species would live for a very long Time, if they were to be never diſſolved by Motion, nor ſpoiled by Idleneſs: for the Body being too much exerciſed, renders all the ſmall Veſſels callous; and too much Reſt cauſes Stagnations and Obſtructions of the impervious Humours. The Medium therefore betwixt Idleneſs and violent Exerciſe ought to be encouraged, to render the Humours pervious through the Veſſels, and diſpoſe the Body to long Life.

[3] The Perception of an unuſual Heavineſs in the Body, gives ſome Reaſon to fear that Diſeaſe is at hand; and therefore let the Body be exerciſed 'till a Sweat begins to appear, but yet not to ſuch a degree as actually to produce a Sweat, but only a ſlight Moiſture of the Skin. Thus if the Diſorder is removeable, it will be carried off by reſtoring the Perſpiration, and the equable Action of the Solids and Fluids upon each other. Nor can Perſpiration be reſtored before the Parts have thus recovered their healthy State. This Motion or Exerciſe of the Body before Meals, is likewiſe one of the beſt means to reſtore a languiſhing Appetite. But we perſpire more in twenty-four Hours by a gentle Exerciſe, than if we uſe ſuch a violent Motion of the Body as to produce a Sweat. For although a larger Evacuation is made in a ſhorter time by Sweat, yet that will ſtop after a while, and the remaining Part of the Day will be attended with a leſs Perſpiration from the ſupervening Cold; whereas if you only exerciſe the Body ſo as to increaſe the inſenſible Perſpiration, the Skin will remain in a kind of warm Atmoſphere, and continue to perſpire.

[4] *Celſus* obſerves that this Exerciſe renders the Body light, only upon certain Conditions, when he ſays, that Venery ſeldom uſed ſtirs up the Humours of the Body to a briſker Motion, but too frequently uſed diſſolves and conſumes them. Thoſe who have laboured under a Gonorrhæa, who ſweat profuſely, or diſcharge too great a Quantity of Saliva or Urine, all ſuch Perſons perſpire leſs than others. They who have taken a purgative Medicine find themſelves oppreſſed with a ſort of Heavineſs, ſome time after the Operation of the Medicine, and this notwithſtanding they diſcharged three Pounds of inteſtinal Fæces; for the *Sanctorian* Perſpiration is by that means diminiſhed, which in a healthy Perſon is of itſelf more than equal to all the other Excretions. The ſame is alſo true of the Sweat, after which the Body is found to be likewiſe heavier.

[5] It is not a little ſurpriſing how much Sleep conduces to Perſpiration. Sleep is neceſſary to Health, and therefore ought not to be neglected, as many have taught. Thoſe who break their Sleep in order to make the Night-hours as the beſt Time for their Study, do not act agreeable to Nature; for by ſtudying in the Night-time, Sleep creeps upon the Body, and the Intellects are not ſo acute. We ſleep more in the Winter time, and we are in that Part of the Year ſtronger. But no Sleep naturally follows unleſs the Body be moderately warm, for we do not reckon that Lethargy which is induced by the moſt ſevere Cold to be a true kind of Sleep, for it is in reality a Diſeaſe. When we ſleep therefore, the Body is ſuſpended as it were in a vaporous Bath, namely, in the Atmoſphere of its own perſpirable Vapours confined by the Bed-cloaths. But how great a Power the retained Exhalations of the

human Body have upon the Skin, is evident from the Application of Emplaſtures, under which the obſtructed Parts are mollified, not by the Virtue of the Plaiſter, but by the perſpirable Matter itſelf, which is repelled and confined by the Plaiſter, ſo as to adhere to the Surface of the Skin in the Form of moiſt Drops. In Sleep therefore the cutaneous Veſſels are mollified, and rendered extremely pervious, ſince the Perſpiration is at that time larger than at any other. But too much Sleep is prejudicial, as *Sanctorius* obſerves, ſince it renders the Body ſtupid, and apt to retain the Matter, which ought to be tranſpired in the Day time.

[6] * To ſleep with the Body uncovered is extremely dangerous, ſince it obſtructs the Perſpiration, and cauſes the worſt Diſeaſes; only the ſleeping one Night in the open Air in the hot Countries, produces the moſt dreadful Diſeaſes; compounded of a Palſy and Convulſions, termed *Beriberi.* Even in *Europe*, if young Men ſleep with their Bodies uncovered, they become rheumatic when they grow old, and are troubled with the Gout irremoveably fixed.

[6] *Lower* has ſupplied us in another manner with the true Time for ſleeping. For if a healthy Perſon faſting takes a large Quantity of Milk, Water, and Bread boiled together, the Blood which is drawn from a Vein ſeven, eight, or nine Hours after, has a ſort of Chyle like Cream ſwimming upon it (§. 131.) But if a Vein is opened ten or twelve Hours after, there will be a yellow Serum inſtead of Chyle. Therefore the Perſpiration does not ſucceed well, until all the crude Juices derived from the Aliments are firſt digeſted or attenuated by the vital Powers; and this cannot be expected before ten Hours are paſt after the Meal.

[7] Leſt the Blood being preſſed from the Surface of the Body, ſhould flow in too great a Quantity upon the Brain, which is free from the ſame Preſſure. And beſides this, a Perſon who lies covered with too many Cloaths is obliged, by the Senſe of the Oppreſſion, to move and turn himſelf about in the Bed, which obſtructs the Perſpiration. But we learn from Experience, that the moſt violent Labour, or long fatiguing Journey, does not tire a Perſon ſo much as often turning and toſſing about in the Bed during theSpace of one Night.

[8] *Sanctorius* has laid it down as a Rule founded on Experience, that extreme Joy increaſes the Perſpiration ſo much, as to ſuddenly exhauſt the Body of its thinner Juices, and prevent the animal Spirits from following in a continued Courſe through the Nerves: and hence it is that more have been known to die with extreme Joy, than with Grief. We read of a Woman, named *Lacæna*, who being perſuaded that her Son was killed by the Enemies Swords, when ſhe ſuddenly ſaw him return not only alive, but adorned with the Marks of Victory, ſhe expired in embracing him. I knew an Inſtance of a Girl, who went from *Holland* into *Aſia* to ſee her Brother; but he expecting her, order'd a ſplendid Equipage of Plate to be got in Order, and commanded his Servants to furniſh a magnificent Houſe for their new Miſtreſs his Siſter; but ſhe being ſurpriſed at his vaſt Riches, and overjoyed with his Kindneſs, expired in the Conſternation. But moderate Paſſions of the Mind, accompanied with Joy, conduce much to Health.

[9] The Fleſh of Mutton or Lamb, Poultry, Pigeons, *&c.* is ſoon digeſted, eſpecially when dreſſed with Onions, Garlick, and other Spices. But Lard or Bacon, and all fat Subſtances, diminiſh Perſpiration. *Sanctorius* has handled this Mat-

ter very well in his Aphoriſms, in which he has given us more Inſtruction than has been wrote concerning the Nature of the Aliments in the vaſt Volumes of the Ancients. But Perſpiration ſucceeds the beſt, when lean Meat is taken ſparingly, and with ſolid Bread, and the drier the Fleſh, or the harder the Bread, ſuch as Biſket, the more eaſy is it to be digeſted, provided the Organs are ſtrong enough. The Slaves which row the Gallies in the *Mediterranean* live very well in Health only upon Biſket Bread, Vinegar and Water, ſo as to undergo the hardeſt Labour continually, without being able to get any Sleep, but what they take in an erect Poſture. Roaſted Meats are more perſpirable than thoſe which are boiled; and Biſket-Bread is more eaſily attenuated in the Blood, than a Decoction of Barley. But fat Subſtances obſtruct the ſmaller Veſſels, and impede Perſpiration; or even if they are externally applied, they excite an Inflammation. Fleſh Broths eaſily paſs off in Sweats.

[10] Roaſt Meat is lighter than Water, and Biſket-Bread ſtill lighter than Fleſh. They who eat hot Roles or Cakes will perſpire one Pound leſs in the Day than they otherwiſe would, as *Sanctorius* affirms.

[11] The Ancients aſſert, that a pure, dry, cold, and light Air promotes Perſpiration, increaſes the Appetite, and ſtrengthens the Body. But the Air is certainly heavier at that Time, ſince the Mercury in the Barometer ſtands at twenty-eight Inches, when the Air is of a moderate Weight; but if the cold becomes very intenſe, the Mercury riſes an Inch higher. Since therefore the Weight of the Air is increaſed one twenty-eighth Part in very cold Weather, our Veſſels being more compreſſed will contract more ſtrongly, ſo as to act with the

twenty-eighth Part of their Force increaſed. But when the Ancients ſpeak of a heavy Air as pernicious, they underſtand a foggy or cloudy Air, which is lighter, as appears from the falling of the Mercury, which is the loweſt before Rain, when the whole Air is filled with the pendulous Clouds. But the Ancients were deſtitute of the Inſtruments neceſſary for theſe Experiments.

§. 431. But every thing of a contrary Nature to thoſe before-mentioned, as alſo an Increaſe of all the other *Excretions* [1], either diminiſh, ſtop, or deprave this inſenſible Diſcharge.

[1] Such as purging of the Bowels, *&c.* For it is a great and epidemical Error, to imagine the Parts to be in a healthy State, when the Fæces are diſcharged from the Bowels in a fluid State; and from whence many are falſly perſuaded, that the Body can become lighter no other Way than by this groſs Evacuation. For in this Diſcharge by purging, the equable Motion and Diſtribution of the Humours is diſturbed throughout the whole Body, inſomuch that one Pound of Fæces evacuated in a fluid State from the Bowels occaſions two Pounds to be retained, which would have otherwiſe perſpired, whence the Body becomes more heavy than if no ſuch Evacution was uſed: nor ought Purges to be uſed, unleſs the Seat of the Diſorder is in the firſt Paſſages, or unleſs the Motion of the Humours is to be diminiſhed. But it ought not to ſeem ſtrange, that Perſpiration ſhould exceed the other Excretions, for the Extent of its ſecretory Organ is the largeſt of any, no ſmaller than the whole Surface of the Body itſelf; whereas

the Urine is ſeparated only from the Kidneys, the inteſtinal Fæces from the Cavity of the Inteſtines, and the Mucus of the Noſe is ſecerned by the Membrana Schneideriana. In ſhort, all the other Excretions are confined to ſingle and ſmaller Parts of the Body.

§. 432. From hence we may be able to underſtand the Kind of *Matter* [1] compoſing this perſpirable Humour, as alſo the *Cauſes* [2], *Effects* [3], *Neceſſity* [4], and *Uſes* [5] thereof; more eſpecially for promoting the Softneſs and Flexibility of the Parts, and for reſtoring their loſt Subſtance: but it more eſpecially ſerves to render the nervous Papillæ moſt lively, and apt to be affected by Objects, as well as to remain always ready to carry or tranſmit the Impreſſions of thoſe Objects to the Senſorium.

[1] We are not to underſtand *Sanctorius* as if the perſpirable Matter was derived only from the Food or Aliments; for that was an Error or Overſight in him. He ſays indeed, that after taking eight Pounds of Food and Drink, within twenty-four Hours the Body will return to its former Weight; and of the eight Pounds of Aliment three only will be diſcharged by Stool, Urine, Spittle, Mucus of the Noſe, or all other ſenſible Excretions put together; and that therefore of conſequence, the other five Pounds muſt have paſſed off by Perſpiration. But it does not appear that he intends the five Pounds of perſpirable Matter diſcharged from the Body, was derived from the Aliments only; but that for five Pounds of Aliment retained, a like Quantity is perſpired or exhaled from all the Pores of the Body, either from the alimentary Juices, or

from the animal Humours before in the Body. It ſeems much more probable that ſuch Humours which had been highly attenuated, ſhould be capable of paſſing through the exhaling Pores, rather than the thick or viſcid Matter of the Food, Ale, Bread, Fleſh, *&c.* which have not yet been duly attenuated, ſhould exhale in the Form of inviſible Vapour, or be ſo highly ſubtilized within the Space of a Day, as to paſs off by inſenſible Perſpiration. This can by no means be admitted, and even Water itſelf is not believed to be perſpirable immediately by the modern Phyſicians. Dogs ſmell out their Maſters by a very ſmall Quantity of the perſpirable Matter. I ſaw a Dog at *Amſterdam* having loſt his Maſter in a Crowd of People, was therefore obliged to run about continually after the Steps of his Maſter 'till he came to the Houſe in which he had taken up his Reſidence. There are therefore ſome Particles in the exhaling Matter peculiar to every particular Perſon, by the Scent of which the Animal can diſtinguiſh one Man from all others; but this can never be expected from ſimple Water.

[2] The Cauſe is a high Attenuation of the Humours, pervious through all the Series of Veſſels by the Force of the Heart and Arteries, by which alſo the Humours are expelled through the pervious Veſſels, after having been ſufficiently attenuated by the Vis Vitæ: and theſe Cauſes continuing to attenuate and divide the alimentary Matter, it is at laſt diſcharged through the Skin in the Form of inſenſible Vapours.

[3] The Effects are, 1. To evacuate the Matter which has been firſt attenuated by the vital Powers. 2. To relieve the other Secretions; for when more Matter exhales through the Skin there is leſs diſcharged by the other Emunctories. When the

Skin is relaxed the Bowels are conſtipated, ſays *Hippocrates.* 3. That the Matter brought laſt to the Veſſels of the Skin may meet with tranſmitting and excretory Ducts; for if the Matter of Perſpiration was to be confined in the Body, it would ſwell in all Parts to an immenſe Bulk, and the Veſſels would reſiſt the perſpirable Humours which were to be laſt evacuated.

[4] Namely, to diſcharge from the Body whatever Humours are ſubtilized and attenuated ſmall enough to paſs through this Emunctory.

[5] It ſerves to render the Skin and all other Parts of the Body flexible; for that the Body might be moveable it was neceſſary for it to conſiſt of very minute Veſſels, capable of admitting only the moſt ſubtle Humours. Beſides this it was neceſſary for the Body to be ſenſible in every Point of its Surface, and therefore it is covered all over with nervous Papillæ. But the Papillæ when dry grow rigid and become callous; the Prevention of which could not have been effected by the Veſſels which run betwixt the Papillæ: but it was neceſſary for a very thin Liquor to be ſecerned under the Cuticle, by which means the Papillæ and whole Surface of the Skin are continually moiſtened as it were in a vaporous Bath, ſo as to remain ſuſceptible of Senſe and Motion. Hence therefore the perſpirable Matter muſt remain ſome time in the Extremities of the Veſſels before it paſſes quite through them; and that the perſpirable Matter does remain or heſitate ſome time under the Cuticle, may appear from thoſe Tubercles which ariſe in the Surface of the Body, by the ſudden Contact of the cold Air; which cannot be well aſcribed to any other Cauſe than a Conſtriction of the Pores or perſpiring Ducts, by which the Matter is confined. But in thoſe Animals where the Skin is rigid, as in

the Rhinoceros, Elephant, *&c.* which have little more of their Body flexible beſides the Snout and their Legs; in theſe the Perſpiration is but ſmall, while the other ſenſible Evacuations by Urine, Stool, *&c.* are very copious.

§. 433. From hence we may underſtand that by increaſing the Evacuation of Sweat (§. 425.), and by enlarging the ſudoriferous Veſſels, Perſpiration will be neceſſarily diminiſhed by *compreſſing* [1] the ſmaller exhaling Veſſels.

Alſo that by violent Motion and too great *Heat* [2], this perſpirable Matter is turned into Sweat.

Whereas by *moderate* [3] Exerciſe, and moderate Warmth, the inſenſible Perſpiration is very much promoted.

Alſo that nothing is more conducive to promote this inſenſible Evacuation, than gentle *Frictions* [4] continued for a long time.

That Sweat continued to Profuſion for too long a time, relaxes and *weakens* [5] the whole Habit, with a Senſe of Laſſitude or Wearineſs.

Why this ſenſible Evacuation happens more frequently to *weak* [6], phthiſical, and *conſumptive* [7] People; as alſo to thoſe who faint away or are dying, in which Caſes Sweats always happen as a neceſſary Conſequence.

Why Perſpiration is the ſmalleſt *immediately after* [8] a Meal, and a *long time after* [9], or before the next Meal, and this even in a healthy Perſon.

Why Perſpiration is the largeſt from the *fifth*[10] to the tenth Hour after Dinner, or any other Meal.

Why riding on Horſeback, or in a Coach, as alſo ſailing in a Boat, together with violent Exerciſe upon the *Ice*[11], or in the Snow, ſo greatly promote this inſenſible Evacuation.

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[1] The ſudoriferous and perſpiring Veſſels are contiguous to each other, ſo that when the former are dilated, the latter muſt be conſequently compreſſed or diminiſhed; and beſides this, the perſpiring Veſſels are naturally more compreſſible with a leſs Force, ſince they are leſs, and compoſed of thinner Coats than the former. So often therefore as the groſſer Humours are by violent Motion or Exerciſe more ſtrongly urged through the larger Veſſels of the Skin, ſo often will the ſmaller exhaling Veſſels be compreſſed, whence the Perſpiration will be diminiſhed; nor can the ſmaller Veſſels be dilated, until the larger ones are firſt compreſſed. For the Motion of the Blood is greateſt in the Arteries, and ſmalleſt in the Veins; whence it happens, that in the moſt ardent Fever the Skin perſpires little or nothing: even the more violent Exerciſes and warmeſt Medicines are ſo far from increaſing Perſpiration, that they diminiſh it; ſince they impel the red Blood into the ſmaller Veſſels, which are impervious to ſuch groſs Particles, whence the other finer Juices are excluded from entering their proper Veſſels. Add to this, that by Sweat are evacuated thoſe Humours in a thick and viſcid State, which if they had continued in the Body, might have been ſo far attenuated by repeated Circulations, as to paſs off by inſenſible Perſpiration. And for this Reaſon alſo the inſen-

ſible Perſpiration is diminiſhed, namely, becauſe the proper Matter is not ſupplied to the exhaling Veſſels. In ſhort, the ſmall Veſſels are dilated by Heat and Motion; and when dilated, they do not tranſmit the thin perſpirable Matter, but diſcharge Sweat: but Sweat differs from perſpirable Matter, ſince the former is yellow, ſaline, and fœtid; whereas the perſpirable Matter is deſtitute both of Colour, Smell, and Taſte.

[2] I went into a Sugar-baker's Workhouſe at *Amſterdam*, in which they are obliged to uſe a great Heat to dry the Loaves; to which Heat the Workmen being accuſtomed, they ſupported it well enough; but yet I not being accuſtomed thereto, was not able to ſuſtain the Heat for above three Minutes before the Sweat ran down me. *Bernier*, in his Journey made with the Mogul's Court into *Cacheir*, writes to his Friend, that in aſcending the Mount *Bember*, which riſes ſteep from the Plain of *Indoſtan*; " I melt away, ſays he, in " Sweats; I drink to no purpoſe, for the very " next Moment I am equally as hot and thirſty as " before."

[3] In Sleep the Humours are equably diſtributed through the Arteries and Veins; whereas in the Time of a Perſon's being awake, their Diſtribution is unequal, more Blood being impelled into the Arteries when the Body is exerciſed, and more collected in the Veins when the Body is at Reſt. Hence therefore in Sleep the Circulation is more equably and perfectly carried on, while the vital Powers are at the ſame time more advantageouſly applied; by which means the Humours are ſooner attenuated, and all the Veſſels render'd freely pervious. The ſame alſo follows from moderate Exerciſe, which comes between Reſt and hard Labour, by which the Arteries are ſo filled, and the

Veins are ſo moderately emptied, that neither of thoſe Veſſels are too much dilated. If theſe Cauſes are increaſed, that is, if the Blood is moved more impetuouſly, the larger Arteries will then be diſtended, ſo as to compreſs the perſpiring Veſſels; and ſometimes the ſanguiferous Arteries become ſo turgid, as to force their contained Blood into the ſerous Veſſels, which is alſo a manifeſt Conſequence from the drinking of Tea. Alſo in a ſlight Fever, if the Matter is not diſcharged by a plentiful Perſpiration, but is ſuddenly checked or ſuppreſſed, it may ſettle or ſtagnate in ſome Parts, and form ſcirrhous Tumors. If Exerciſe is not followed, then the Humours are not ſo well attenuated, and conſequently they will not be perpetually impelled through the ſmaller Veſſels. It is therefore evident, that a Medium is to be followed betwixt theſe two Extremes, of violent Motion, and too great a Reſt of the Humours; and it is alſo evident, that Fevers may as well ariſe from a Suppreſſion, as from too great an Increaſe of this Evacuation.

[4] *Galen* had ſo great a Dependance on and eſteem for this Remedy, that he has wrote a whole Book concerning Friction. The Ancients after placing the Perſon in a Stove, rubbed the Skin with dry rough Cloths made warm, by which means they highly attenuated the Humours, and at the ſame time increaſed the Power or Action of the Veſſels; and by theſe means Perſpiration may be reſtored after it has been a long time ſuppreſſed. I even lay very little Streſs or Dependance upon any other means in chronical Diſorders. I had under my Care a young Man whoſe Abdomen felt ſo hard and diſtended to the Touch as if it contained Pieces of Wood; but yet I reſtored this Patient to a perfect State of Health by a con-

a conſtant Uſe of Mead, with the Uſe of Frictions repeated every Day. But the Meaſure of the Friction is to be determined by the Return of the natural Heat, for if it be increaſed beyond that, more or leſs of a Fever is produced.

[5] Sweat if it is not critical weakens the Body in all Diſorders, becauſe it evacuates the uſeful together with the excrementitious Humours; for ſince the more ſubtle and groſs Juices will be expelled together, the nutritious Juice with the nervous Fluid or Spirits will eſcape together. Beſides this, too much Sweat interrupts or weakens the continued Preſſure from the Heart to the ſmalleſt Arteries in the Encephalon; and from hence Weakneſs and Faintings follow.

[6] Thoſe who are afflicted with an acute Fever, have their Skin always dry; but when Death approaches, a yellow, fœtid, viſcid, and cold Sweat appears all over the Body. In this caſe then all the minute Valves which cover the Mouths of the ſudoriferous Veſſels, with all the cutaneous Sphincters are relaxed, and from hence the Humours which were before accumulated in thoſe Veſſels meet with a ready Diſcharge after the Reſiſtance is taken off. For it muſt be obſerved, that not only the Mouth, Eyes, urinary Bladder, *&c.* are provided with their proper Sphincters, but even every Veſſel and Part of the Body have a contractile Power, by which they exclude every thing injurious. When a Perſon is invaded with the Plague, he perceive a Senſation as if cold Water was poured over him, whereupon all the cutaneous Sphincters are contracted: but it is alſo, from a Relaxation of the Sphincters, that dying People often evacuate their Urine and inteſtinal Fæces inſenſibly, at the ſame time when theſe Sweats appear. But theſe Sweats are cold from the Stagnation

nation of the Matter without the Courſe of the circulating Humours, and from the Weakneſs of the vital Powers.

[7] One principal Action of the Lungs is to compact the thin Blood into denſe Globules; for when the Lungs are injured, or their Function impaired, the Chyle then retains its crude and watery State, and all the Humours melt away and run off by the ſeveral Emunctories (§. 204.) Hence riding on Horſeback is a kind of vicarious Remedy to anſwer the Office of the Lungs upon the Blood. For when a Perſon rides againſt the Air, it has the ſame Effect upon the Lungs as if the Air was render'd heavier; for it is the ſame thing with reſpect to the Lungs, whether the Air be made four times heavier, or moved four times more ſwiftly into the Lungs: to which add the infinite Number of Succuſſions, by which the Blood is ſtruck againſt the Sides of the ſmall Veſſels. This Exerciſe was the great Secret of *Sydenham*, which I have happily experienced in many Patients.

[8] Namely, at that time when the Chyle is as yet thick and crude in the Blood, not being attenuated or ſubtilized to ſuch a Degree, as is neceſſary for it to paſs off in ſome meaſure by inſenſible Perſpiration; the whole Effect of which is produced by the vital Powers. *Lower* aſſures us, that Digeſtion is not finiſhed before the fifth Hour after a Meal (§. 87, 129, 204.). Beſides this, the larger Veſſels are at that time more turgid, while the ſmaller Veſſels are compreſſed; this Truth we are aſſured of from the Experiments of *Sanctorius*. From whence it appears, that ſcarce more than twelve Ounces are perſpired during the firſt three Hours after a Meal, whereas within five or ſix Hours from the firſt, the Body is found to be two Pounds lighter.

This

[9] This follows from a Conſumption of the Humours, which when profuſely waſted or conſumed, occaſioned the Veſſels to loſe their contractile Force, whence the Blood cannot be ſufficiently attenuated to prepare and diſcharge the perſpirable Matter. Thoſe who periſh with Hunger do not expire for want of the groſſer Humours, ſince the larger Veſſels are found repleniſhed with Blood, but they periſh for want of the more ſubtle Humours, and from a Collapſion of the ſmaller lateral Veſſels through Inanition.

[10] For at that time the Chyle is elaborated, and converted into Milk; but by the twelfth Hour it is turned into Serum, which is thin enough to exhale in a great meaſure, or at leaſt to ſupply the Place in the Veſſels of thoſe indigenous Humours which have been exhaled from our Bodies.

[11] Perſpiration is this way ſo much promoted, that in three Hours time, the Evacuation amounts to the ſame as ſix Hours Exerciſe in a hot Air. For the cold Air conſtringes the Veſſels, that only ſuch Humours can eſcape as are the moſt fluid: and at the ſame time the increaſed Action of the Body augments the Power and Reaction of the Veſſels upon the Juices; ſo that if Exerciſe to a conſiderable Degree be joined with theſe Circumſtances, by the greater Attrition which is produced betwixt the Veſſels and their contained Humours, a conſiderable Heat of the Body will ariſe even in the midſt of a cold Air; and from hence thoſe Humours which are the moſt attenuated, will be urged through the Pores of the Skin, and carried off by the Air. And this Evacuation is ſometimes ſo much increaſed in a ſhort time, that by interrupting the continued Preſſure of the Humours towards the Encephalon, a Fainting, and

Death itſelf at length follow. Even in *Holland* there are not wanting Inſtances of the voracious Appetite or Bulimy, eſpecially in the *Northern* Parts. When Perſons have been ſcating upon the Ice very ſwiftly for a conſiderable time, they have been known to ſweat profuſely, even in the midſt of the Snows; inſomuch that they have fell down ſuddenly, panting with their Mouth open, and in a Swoon, and in a ſhort time after they have expired. It is uſual in theſe Caſes to give ſpirituous Liquors to the Patient, which muſt be in effect as bad as Poiſon, ſince it too ſuddenly diffuſes itſelf, and by its ſpirituous Nature exhales together with the more ſubtle Humours. Such People ought to be nouriſhed with the moſt compact Aliments, which are not eaſily attenuated but by a conſiderable Action of the vital Powers; ſuch are brown Bread that is very ſolid, Fiſh and Fleſh ſalted and dried in the Smoak, &c. And by this means the too great Action of the Solids upon the Fluids may be eaſily ſupported; hence *Hippocrates* obſerves, that in Winter time the Venters or Viſcera are warmer, and therefore an Addition is to be made in the Aliments.

Of the Nutrition, Growth, and Decay of the Body.

§. 434. TO render the human Body capable of duly exerciſing all the *Motions* [1] of the Humours, Veſſels, and Muſcles without deſtroying them, it was neceſſary for the ſeveral Veſſels, Muſcles, and *Fibres* [2] to be eaſily *flexible* 3; but in order to this Flexibility, the cohering Particles ought *partly* 4 to change their Contact, and partly to remain or continue in their Contacts with each other. But this Change could not be performed, unleſs the larger conſtituent Parts of the Body were made up of the moſt *ſlender* 5, fine, and ſhort Threads, compoſed of minute Particles; nor even then could thoſe Actions be performed, unleſs a *Humour* 6 continually paſſed betwixt the ſmalleſt Fibres and Veſſels to prevent their Concretion, and reſtore ſuch Particles as are loſt; the whole Body therefore, as a flexible Machine adapted to various Motions, ought of neceſſity to conſiſt of *ſmall Veſſels* 7.

[1] The human Body could not have been made ſo as to anſwer all its Offices, if its Matter was the moſt rigid Adamant, or its Parts one continued Statue. For as the Body is made up of innumerable ſmall Machines, each of which have their particular and different Motions aſſigned to them, it was neceſſary that the whole Machine ſhould be compoſed of ſuch ſmall Parts, or more ſimple Machines, as might each of them perform a proper Motion, in ſuch a manner, that though the Actions of each are different, yet that they might receive their common Principle of Motion from one general Cauſe: and thus are they conjoined into one Machine; for all Diſeaſes and Pains are perceived but by one and the ſame Mind, as are all the Motions or various Actions of the ſeveral Parts derived from one common Mover, which is not only ſufficient to continue the various Works of the whole Machine for a

ſhort time, but even for the Space of a Century and half, notwithſtanding the Machine is by various Accidents frequently deſtroyed before that time. For Men of Letters ſpare their Bodies, and conſume or ſpoil their Brains, while the Huſbandman ſpares his Intellects, but renders his whole Body rigid and callous too early in all its ſmaller Parts by hard Labour; while other People again ſubvert and diſturb the ſeveral Offices of their Machines, ſo as to haſten the Deſtruction of the whole, either by too much Reſt, or too much Motion of the Humours and Veſſels, by Errors or Exceſſes in the Non-naturals, eſpecially by Intemperance in Diet, *&c.*

[2] The Bones of the Shoulders or Arms, with thoſe of the Fore-arms, the Radius and Ulna, are ſo connected to each other, that they conform a right Line together, or be inflected upon each other ſo as to deſcribe various Angles; but only let the Mucus confined in the Capſules of the Articulations be dried up and concreted, the whole Limb will then become rigid and immoveable like a Stick; whence it appears, that for the human Body to be moveable, it was neceſſary for it to conſiſt of many diſtinct Parts; and in general, the greater Number of Motions there are to be performed by any Part, the ſmaller are the conſtituent more ſimple Parts, which compoſe the whole.

[3] We call a flexible Body one whoſe Parts ſo cohere together, that they may be changed into any Poſture without breaking or diſſolving their Continuity, or mutual Contacts. But the ſeveral Parts of the human Body were required to be ſuch, as to admit the Veſſels to be dilated and contracted in various Degrees, and for the Muſcles to act in various Directions, *&c.* There is not even a Nerve, Muſcle, Gland, or other ſmaller

Part of the Body, capable of performing its Office when it has once become rigid: but the ſeveral Parts of the whole ought to be flexible in every Point; for if a right Line is to be changed into a Curve, or a Curve into a right Line, the ſmalleſt Points or right Lines which compoſe the Curve muſt each of them change their Situations; and from hence again it is evident, that the ſeveral Parts of the human Body were required to be not only flexible, but to be made up of the ſmalleſt Particles all of the ſame Nature.

[4] Let us take, for Example, two Loadſtones; if the ſame Poles of each Stone are applied together, they will cohere and form one continued Body; but yet their Coheſion will not hinder them from moving freely, or bending either way, even without deſtroying their Coheſion. In the ſame manner two Elements, or primary conſtituent Particles, may be conjoined into a ſmall Fibre, ſo that it may be bent in any Direction without removing the Particles from their mutual Contacts with each other; and this is that Flexibility which does not reſide in the Elements, or conſtituent Particles of the ſmalleſt Fibres, but in their Connection or Coheſion to each other.

[5] If two ſimple Bodies are incumbent one upon the other, they may remain flexible; but when ſeveral Rows of ſuch Bodies lie *Stratum ſuper Stratum*; or, which is the ſame, if groſſer Particles are collected together into one Faſciculus, they will not then be ſo perfectly flexible, notwithſtanding their Flexibility will continue, though not ſo free in every Part. If you ſuppoſe ſeveral right Lines lying by the Sides of each other, it may be eaſily conceived that ſome will be more flexible than others, becauſe the lowermoſt will be formed into a ſmaller Arch, while each of the upper ones

deſcribe larger Arches; ſo that there will be Arches of ſeveral Degrees, in proportion as the Diſtance is greater from the Center of the Inflection to the Circumference, in which the Circles of the inflected Lines are the largeſt. From this Conſideration we may explain how a Body may be itſelf inflexible, when at the ſame time its conſtituent Parts are all of them flexible; and how a very brittle Body may be render'd flexible. Even Glaſs itſelf, which is ſo extremely brittle, being drawn out into a hollow Thread ſmaller than a Hair of one's Head, is eaſily bent or twiſted round any thing, only becauſe of the great Thinneſs of ſuch a ſmall capillary Tube, and therefore there are but very few Strata of the vitrious Particles lying upon each other: but if many of theſe very flexible Threads of Glaſs are collected together into one Faſciculus, perhaps of a thouſand, ſome of them will remain whole, while others are broke, after endeavouring to bend them. A Cable Rope is rigid and inflexible, notwithſtanding it is compoſed of very flexible Threads. Hence therefore it is evident, that the greateſt Tenuity and Flexibility are joined together in the ſame Body purely from the natural Diſpoſition of its Parts: and it is alſo evident, why the Creator has compoſed our Bodies of the ſmalleſt Fibres.

[6] This is a common Property of the Fibres of a human Body, namely, that if one comes into Contact with another without the Intervention of a Fluid, they immediately cohere together. If an Ulcer has conſumed Part of the Fingers, and the naked Surfaces of the two Fingers are applied and retained together by Bandage, they will grow together within the Space of a ſingle Night. Sore Eye-lids and bleeding Lips do likewiſe eaſily grow together, unleſs they are cautiouſly prevented.

The Canalis Arterioſus, Venoſus, Foramen Ovale, with the umbilical Veſſels, though large Tubes of a conſiderable Diameter, do nevertheleſs grow together ſo ſoon as the Blood ceaſes to flow through them in the new-born Infant. But if this happens in the larger Veſſels, how much more readily will it ſucceed in the ſmaller ones? But if ſeveral ſmall Fibres are conjoined together into one Thread, they cannot be ſeparated by the Interpoſition of any Humour, unleſs the large Thread itſelf is hollow: and therefore thoſe Threads which are made up of the ſmalleſt and moſt ſimple Fibres, muſt neceſſarily be hollow; but if the Cavity of ſuch a ſmall Veſſel, compoſed of the minuteſt Fibres, is obliterated by Labour, old Age, or a Denial of the Juices paſſing into it, the Flexibility, Motion, and Uſe thereof is deſtroyed by the Concretion of its Sides.

[7] But it was not only neceſſary for the ſeveral Threads of the Body to be formed pervious, but they were alſo required to be ſeparated from each other by the Intervention of Juices flowing thro' them; for the ſmalleſt Veſſels and Fibres grow together, as well by a Stagnation of their contained Humours, as by a Collapſion and Vacuity of them. If the Blood ſtagnates but a ſmall time, it congeals into a ſolid Maſs, and coheres with the Sides of its containing Veſſels. If the Blood ſtagnates but a ſmall time in the Aorta, as it does in thoſe who are ſubject to Faintings away, there are very often Polypus's found after Death adhering to the Sides of the Heart; and therefore the Humours ought to flow freely betwixt the Sides of the ſmalleſt Fibres and Veſſels. But the Motion of all the Humours in the Body is derived from one common Mover the Heart, to which the larger Veſſels are immediately continuous: but from the

larger Veſſels ariſe the ſmaller ones, which diminiſh in ſeveral Orders down to the moſt minute; and therefore the Humours are moved through the Cavities of the ſmalleſt Veſſels by the Force of the Heart.

§. 435. But this very Motion being *continually* [1] and violently performed in Veſſels of ſuch a *tender* [2] Fabric, muſt neceſſarily occaſion the ſmalleſt Parts to be broke or rubbed off from the ſolid Fibres by the continual Impulſe of the Humours and Actions of the Muſcles; which abraded Particles mixing with the Humours, are at length circulated together with them, and diſcharged from the Body moſtly in the Form of Exhalations; in the mean time the Fluids being continually leſſened, or ground ſmall by Attrition, are at length propelled to the exhaling Veſſels, and evacuated from the Body; and from hence the living Machine of the Animal *ſoon* [3] deſtroys itſelf from the very Condition of its Frame.

[1] The ſeveral Juices which are moved through the Veſſels of the human Body, muſt neceſſarily cauſe a great Attrition. The celebrated M. *Amontons*, in a Treatiſe concerning the Attrition of moving Bodies, has demonſtrated that the Friction of Bodies moving upon each other, is a very great Impediment in Machines, ſo as to equal almoſt a third Part of the Weight to be moved. *Mem. Acad. Reg.* 1699. *p.* 257. Since therefore there are above ſeven thouſand times two Ounces of Blood expelled from the Heart into the Arteries in an Hour, it

is eaſy to conceive that the internal Sides of the Veſſels muſt be abraded, or wore away.

2 A ſanguiferous Veſſel, which is the largeſt of the ſmaller Veſſels, is no thicker than the tenth Part of a Hair of one's Head; but then there is an incredible Diminution or Diſtance betwixt the largeſt of the ſmaller Veſſels, and the very ſmalleſt of all, ſince the Diameters of the decreaſing Series of Veſſels are continually anſwerable to the Particles of the Humours which are to flow through them; ſo that there ſeems to be an infinite Number of Series interpoſed betwixt the ſmalleſt ſanguiferous and pellucid Veſſels. But yet it is neceſſary for Humours to be contained in thoſe ſmall Veſſels, which Humours muſt alſo paſs ſwiftly through them to prevent their Concretion. But how minute or fine are theſe ſmalleſt Veſſels, if we conſider the Subtlety of the Juices which flow through them. The Brain itſelf, which is entirely a Compages of ſmall Veſſels, is ſo tender, that it may be divided by a Blaſt with one's Breath, after the Pia Mater has been taken off; and therefore if you compare the perpetual Motion of the Humours with the exceeding Minuteneſs and Tenderneſs of the Veſſels, it will apparently follow, that ſome of the conſtituent Particles of thoſe Veſſels muſt be continually abraded and carried away by the refluent Humours. But ſince the largeſt Veſſels are not only pervious to their contained Humours, but are alſo compoſed of ſmaller Veſſels, they will therefore conſequently be deſtroyed both by the Action of themſelves, and of the ſmall Veſſels of which they are conſtituted. Unleſs therefore the Body is continually ſupplied or nouriſhed with the other Particles, to fill up the Places of thoſe which were abraded, the Body will ſoon periſh. Even a ſmall Veſſel, which in the laſt Series ſeems to be

perhaps

perhaps a thouſand times ſmaller than a Hair of one's Head, is perpetually deſtroyed, and again regenerated. But theſe conſtituent Particles, or Elements of the Solids, abraded from the ſmalleſt Veſſels, and reduced to a fluid State by Attrition, certainly make a large Portion of the perſpirable Matter of *Sanctorius* (§. 432.)

Thus the Body naturally deſtroys itſelf from its own Nature; and the Animal no ſooner begins to live, than to approach towards Death, which is the Conſequence of Life. The greateſt Period of Life is a Century and a half; but from what has been ſaid before, we may underſtand why Perſons are more liable to Diſeaſes and Death, as they are younger or nearer their Birth; for more periſh in the firſt Month of Life than in the ſecond, and more in the firſt Year than in the ſecond; for the Strength and Permanence of the Body increaſes with the Age. I made uſe of this Argument to keep up the Spirits of an old Man of ninety Years, who was afraid of Death without any Reaſon.

§. 436. It is therefore *neceſſary* [1] for the due Continuance of Life, and the Maintenance of the ſeveral Parts of the Body in their ſound or natural State, that as much, or *as many of the ſame Kind* [2] of ſolid and fluid Particles ſhould be perpetually reſtored, as are continually waſted by the ſeveral Actions of Life; and this Reſtitution is called *Nutrition* [3].

[1] From the Age of twenty-five to fifty Years, the human Body receives ſcarce any Alteration; but, as every Day a large Part of its Subſtance is conſumed, ſome Addition muſt be neceſſarily made to reſtore the loſt Subſtance, namely, almoſt the whole Subſtance of the Bread and

other Food, except the Bran and groſſer Parts is converted into Chyle, Milk, Serum, and Blood; but Serum in the Space of twenty-four Hours is ſubtilized to a very great Degree of Tenuity, in the ſame manner as the White of an Egg is ſo highly attenuated within a certain Space of Time, as to be capable of nouriſhing the incipient Chick; and of the ſame Nature with the attenuated Albumen of the Egg, is that Juice which repairs the waſted or loſt Subſtance of the Body.

[2] Thus *Sanctorius* affirms, it is neceſſary for the Body to be ſupplied continually with as much Matter of the ſame kind as is continually conſumed or carried off from the Body. He that can perform this one Point, is acquainted with the Art of preſerving the Body immutable to extreme old Age; but if more is added to the Body than is conſumed, it will be oppreſſed or overloaded; if leſs is added, the Body will waſte or decay.

[3] The Reſtitution of the loſt Subſtance in the Body is twofold, the one by which the ſolid Parts are repaired, and the other by which the exhauſted Juices are ſupplied: for in the Juices, as we before obſerved, there are at leaſt five Pounds loſt by Perſpiration in a healthy middle-aged Man in the ſerene Air of *Venice*. But the ſolid Parts of the Body are alſo abraded or worn away in ſo much a larger Proportion, as the Parts are exerciſed with a more violent Motion. If the Urine of a Horſe, which has ſtood idle for ſome time in a Stable, be viewed with a Microſcope, you will perceive ſmall Spiculæ floating in it; but if the Urine of the ſame Horſe be at another time examined, after he has been well exerciſed or fatigued with Labour, thoſe Spiculæ or ſolid Corpuſcles obſerved floating in the Urine will appear a hundred times more numerous; from whence it ma-

nifeſtly appears, that by muſcular Motion or continual Exerciſe of the Body, many of the ſolid Parts are wore off from the Fibres and Veſſels (§. 379.) But how long a time a Man may live without Aliments, may appear from the notable Inſtance of a noble Captain in our Army, who being weakened by the Wounds which he had received, lay among the Dead for the ſpace of three Days and Nights, till on the fourth Day a Woman who came to make Spoil of his Cloaths, *&c.* perceiving ſome Motion in the half dead Man, carried the News to the Camp, and he was by proper Means recovered; from which time he has ſurvived for the ſpace of forty Years to the Advantage of the Republick. But this is nothing in compariſon with the Hiſtories we have of Abſtinence or Faſting continued for ſeveral Months, or even Years.

§. 437. The *Humours*[1] which are conſumed or exhauſted, are again ſupplied as to their Matter by the ſolid and fluid Aliments, as alſo in part from the external Air; but as to the neceſſary Qualities of that Matter, thoſe are produced by the concurring Powers of the ſeveral Parts of the Body which we have hitherto explained, by which the nutritious Matter is formed and applied by the reſpective Veſſels: and this is what we are treat of in this Place.

[1] The Nutrition or Reſtitution of the fluid Parts of the Body conſiſts in the Air, Water, and Juices of Vegetables and Animals taken into the Veſſels, depoſiting their own Nature and acquiring that of human animal Fluids; that is, for them to change their Nature ſo as to be converted into Blood, Se-

rum, Lymph, animal Spirits, *&c.* and Nutrition is then compleated, when ſo much of every Claſs of the Humours is reſtored in Proportion to the Loſs or Conſumption which is daily made in each by the Actions of Life. Thus the ingeſted Aliments are firſt changed into Chyle, the Chyle into Serum and Blood, and the Blood itſelf into the ſeveral Orders of more ſubtle Humours, which are prepared in the ſeveral Parts of the Body. But we are not to imagine that Repletion and Nutrition are the ſame; for by Repletion we underſtand an Accumulation of ſo much Matter as was exhauſted from the Body, whereas Nutrition reſpects not only the Quantity but the healthy animal Qualities of the ſame Matter; that is, when the Body retains its proper Weight, but the Juices continue in a crude State without being properly aſſimilated into healthy animal Juices. Thus after a profuſe Hæmorrhage, it is no difficult Matter to render the Body of the ſame Weight, by filling the Veſſels merely with Water or watery Liquors; but this Repletion of the Veſſels does not repair the Functions of the human Body, to do which the Blood alone is adapted; but the whole Body becomes weak and unactive, the Juices retain their crude or indigeſted State, and the Water eſcapes and ſtagnates in the ſmaller Veſſels and Cells of the Body, whence a Cachexy. And in general, if the Body is deſtitute of Strength, whatever Aliment is taken in does not nouriſh, but remains crude or indigeſted. And from hence we may underſtand how injudiciouſly Infuſions and Transfuſions of Blood and other Liquors have been abuſed by Phyſicians, upon little or no Foundation for repairing the vital Powers of the Patient. The bad Succeſs of theſe Experiments in *France*, *England*, and *Germany*, is ſufficient to demonſtrate, that every living Creature ought to prepare its own Blood, and that one Man or Animal cannot receive it from another ſo as to reap any Advantage. But if to a Perſon who is thus pale and bloodleſs, we give Bread, Milk, and Fleſh Broths in ſmall Quantities, and at frequent Intervals, both the Fleſh-Broths and Bread will then be converted into the healthy vital Juices of the Patient by the Powers of Life, or the Actions of ſeveral Organs which we have hitherto explained, whence a true Aſſimilation or Nutrition will follow.

§. 438 But the Nutrition or Reſtitution of the ſolid Parts, though ſomething more obſcure than that of the Fluids, is yet intelligible from a Knowledge of the following Particulars.

§. 439. Every ſolid Part of our Bodies is compoſed of *other* [1] leſſer Solids exactly reſembling the larger; the Veſſels are made up of ſmaller *Veſſels* [2], the Bone of ſmaller Bones, the Muſcles of ſmaller Muſcles, *&c.* which Courſe is continued in the Compoſition of the Parts even beyond the Limits of Senſe, aſſiſted by what Art ſoever, as we are aſſured from the accurate Experiments of *Malpighi*, *Ruyſch*, *Lewenhoec*, and *Hooke.* But yet this Diviſion ſcarce proceeds *in infinitum* [3], as appears by the Nature of the Humours and alimentary Juices.

[1] An Artery is compoſed of ſmall Arteries, a Vein of ſmall Veins, the Nerves of ſmaller Nerves, and the Muſcles of ſtill ſmaller Muſcles, *&c.*

[2] The largeſt of the Veſſels in the human Body is the Aorta among the Arteries, and the Vena cava among the Veins; though the laſt, together with the Heart, are rather Receptacles. But the large Artery, called Aorta, is compoſed of ſeveral Membranes, which receive ſo many Blood-veſſels from the coronary Arteries, that within the Compaſs of an Inch of its Membranes there are more than a thouſand Myriads, each of which are diſtinguiſhable to the naked Eye, after they have been injected according to the Artifice of *Ruyſch*; inſomuch that the whole Artery ſeems to be compoſed, not of Membranes, but of mere Veſſels interwove together, much after the ſame manner as ſome ſort of Stuffs are wove of flexible glaſs Tubes, which are extremely minute; for the ductile glaſs Threads are always hollow. Such an Intertexture very much reſembles the Membranes of our Bodies, of which the Veſſels themſelves are compoſed. Nor are the ſanguiferous Arteries themſelves only vaſcular, but all the ſmaller Series of Arteries are likewiſe compoſed by an Intertexture of others ſtill ſmaller down to the very laſt, which not being vaſcular is compoſed of a mere ſimple Membrane.

[3] There have been ſome Geometricians of Note, who have aſſerted that this Diviſion was infinite; and indeed it is true that it eſcapes our Senſes, nor can we penetrate to the End of this Diviſion by the Help of Microſcopes, Injections, Putrifactions, or Diſſolutions of the Parts; neither of which will conduct us to the ſmalleſt Elements, or conſtituent Particles of the Body. *Hartſoeker* has informed us of an Animal no larger than the hundredth Part of a Grain of Sand, which lays three hundred Eggs; and in general it is obſervable that Inſects are the more prolific, as they are more minute. But how ſmall muſt be the Veſſels in ſuch

a minute Animalcule? But the Particles of the Blood are of a determinate Magnitude; and the leſſer Particles which follow in ſeveral Orders to the red Globules, are each ſix times leſs than the other; ſo that the Particles or Globules of the thouſandth Order will be to a red Blood Globule, as the Power of a Fraction of a thouſand by $\frac{1}{6}$ is to Unity. But the Diviſion muſt neceſſarily ſtop ſomewhere, ſince the human Body is a limited Being, and ſince we find that the Magnitude of the Veſſels is determined, the Aorta being the largeſt; and as a Perſon is ſoon refreſhed after being fatigued by Labour, barely by the Aſſumption of a moderate Quantity of Aliments; whereas it does not ſeem probable that the Aliments could be divided into ſuch minute Particles in ſo ſhort a time, as to correſpond to ſuch infinitely ſmall Veſſels.

§. 440. But *Microſcopes* [1], Injections, the ſmalleſt Wounds, bliſtering Remedies, *Conſumptions* [2], and a withering of any Part inform us, that our Solids are but a very ſmall Portion in compariſon with our fluid Humours; even it is almoſt demonſtrable, from conſidering the *Origin* [2] and Formation of the Veſſels, and from reſolving the larger Veſſels into the ſmaller ones of which they are compoſed, that the ſolid Maſs of the whole Body is almoſt wholly compoſed of mere *Nerves* [4], which lay the firſt Baſis of the ſolid Elements or ſmalleſt Threads of the Body.

[1] If any Part of the Body be examined by the naked Eye, it ſeems to be a mere Solid; but yet in ſuch a ſmall Particle of the Body, no larger than the hundredth Part of a Grain of Sand, the Mi-

croſcope demonſtrates innumerable ſmall Veſſels, each filled with their reſpective Juices (§. 214.)

3 It is almoſt incredible what a ſmall Portion of the Body is compoſed of mere Solids. If we ſubtract from the human Body all the Cavities, Veſſels, and Receptacles, together with all the Juices, there will then remain ſo ſmall a Portion of a ſolid Maſs as to be almoſt inconſiderable. In a Horſe that appears in good Condition almoſt half his Body is mere Fat (§. 396, 416. N°. 4 and 5.); and by fattening he may acquire almoſt as much Weight again. If you take a very fat Ox to the Plough and exerciſe him with unuſual Labour, he will become ſo lean, that after taking out the Stomach full of Graſs, Hay, or other Food, with the ſeveral Viſcera, which increaſe the Weight of the Carcaſs without being properly a Part of it, he will be reduced to the tenth Part of his former Weight; but if ſuch an Ox reduced to the laſt Degree of Poverty be put up in the Stall to feed and reſt, he will recover his former Weight. I have obſerved ſtrong muſcular Men with large Limbs, who after falling into an Hæmoptoe or a Conſumption, have been ſo much waſted, that they have retained little or nothing of their former Bulk, their Bones being but looſely covered by the Skin, through which the Thigh Bones may be eaſily felt, when at the ſame time no Part either of the Veſſels or Muſcles was deſtroyed, only their Juices exhauſted. Even the Bones themſelves which ſeem ſo compact and hard, loſe almoſt all their Weight after they have been calcined in the Fire, and deprived of their Juices and Fat. Men who have gradually corrupted for many Ages in Sepulchres, ſeem at firſt Opening of them to retain their former Shape, but they are no ſooner touched, but the whole Figure of Man falls into a ſmall Quantity of

Duſt. After *Alexandria* was taken, *Cæſar*, who was afterwards *Auguſtus*, had the Curioſity to viſit the dead Carcaſs of *Alexander* of *Macedon*; he indeed ſaw him in his Coffin, but was ſhocked to find the Conqueror of the World fallen into a ſmall Quantity of Duſt or Aſhes. We have ſeveral accurate Experiments made in this reſpect by *Keil*. He uſed a Balance like that which Mr. *Boyle* has depicted in his Hydroſtatics, and ſuch as they make at *Amſterdam*, which I have ſometimes bought at the Price of an hundred Florins; this kind of Balance is ſo exact that the hundredth Part of a Grain will turn the Scale, and cauſe it to deſcend. He placed upon ſuch a Balance a Portion of the human Brain, and obſerved that every Moment it was neceſſary to add ſome Weight to the Scale to maintain it in Equilibrio, ſince the Brain grew continually lighter, 'till it was reduced to one twentieth Part of its Maſs. Hence therefore it appeared, that nineteen Parts in twenty of the Brain were Fluids and exhaled from it. Nor ought it to be objected that many Parts of the Body appear ſufficiently hard to the Senſes, for their Reſiſtance is derived chiefly from the Fluids which are contained in the Veſſels. Even a Bladder that is very full feels as hard as a ſolid Body, notwithſtanding it was of itſelf extremely ſoft and flexible.

[3] One of the principal Obſervers of Nature, *Malpighi*, aſſures us of this (§. 276.). For a Hen which has been ſeparated a Fortnight from the Cock, lays Eggs in all Appearance nothing inferior to thoſe of a Hen which has been lately trodden. After placing ſome of the former infœcundated Eggs under the ſitting Hen they putrify in a few Days time, and the Albumen being attenuated exhales through the Pores of the

Shell, while the Yolk only remains within the Shell in a putrid State. Hence ariſes that Suſpicion of an Egg being unſound that does not appear full, namely, one whoſe Membrane in the obtuſe End of the Shell has been rarefied or broke. But *Malpighi* having ſet ſome Eggs of the ſame Hen after being fecundated by the Cock, they brought forth Chickens after twenty one Days, which were ſo increaſed by exhauſting the Albumen, that they weighed heavier than the Egg itſelf, namely, an Ounce or an Ounce and half. In the mean time we meet with one conſiderable Difference betwixt a ſterile and prolific Egg, namely, that in the Sacculus placed at the obtuſe End of the Egg full of cryſtalline Liquor, there is a ſmall red Point in the fecundated Egg, which is abſent in thoſe which are ſterile. From that red Point the Carina or incipient Chick begins to be formed within a few Hours; firſt appears the Medulla Spinalis with two other Points, namely, the Brain and Cerebellum; to which are added, after twelve Hours time, the two Eyes, or a new Pair of ſmall Bladders; and at that time the whole Animal appears to conſiſt of nothing more than the nervous Syſtem, without either Heart, Lungs, Liver, or any other of the ſanguiferous Veſſels. But in a little time after, a kind of Ring is appended by degrees to the Carina, which is contorted at length into four venous Sinus's, which being conjoined together form the Heart, namely, the two Auricles and Ventricles. In the next place, the Lungs, Liver, and other Viſcera begin to appear; and this Method is followed by Nature, not only in the Chick, but in the human Species, in which at firſt there is little more than the Head, to which the other Viſcera are added by degrees.

[4] We are from this Argument perſuaded, that Nutrition is carried on by the Nerves, becauſe the nutritious Humour is not applied to the Veſſels by their internal Surface, but by other ſmaller Vaſcules of which they are compoſed; the ſmalleſt or laſt Series of which are the Nerves; the laſt Series but one is an Intertexture of the preceeding Order, and ſo of the reſt, which are derived ſucceſſively from each other. When therefore the larger Veſſels are nouriſhed, ſo muſt alſo the ſmaller, and even the ultimate Veſſels, of which the large ones are compoſed, be likewiſe nouriſhed; but theſe ultimate Veſſels are ſmall Nerves (§. 302.), for a Nerve we call that Veſſel which is the ſmalleſt or ultimate.

§. 441. And, in truth, all this Maſs of the Body, except an incredibly ſmall Particle, grew up from thoſe Humours which were before *extremely ſubtle* [1], namely, the fluid Colliquamentum, which is very much like the nervous Juice, as *Malpighi* has demonſtrated by his repeated Obſervations in his Treatiſe *de Ovo incubato.*

[1] I have a human Fœtus by me no larger than an Ant: and yet from ſo ſmall a Fœtus, within the Space of nine Months, is formed an Infant weighing ſeven or eight Pounds: but this Addition of Weight and Matter could be made no other way than by the umbilical Veſſels, or from the Liquor of the Amnios. The Humours which enter'd by the umbilical Veſſels, were derived from the Uterus by Ways as yet obſcure, tranſuding through a Membrane as compact as the Cuticle itſelf. Both theſe Liquors muſt therefore be extremely ſubtle.

In the Chick the Nouriſhment is derived from the thinneſt Part of the Albumen, which being ſlowly prepared, is at length propelled, in the Sacculus of the Colliquamentum; and yet from ſo thin a Liquor are derived, in the Space of twenty Days time, Parts ſo compact as the Bones, and ſo tough as the Tendons.

§. 442. Nor does the White of the Egg nouriſh before it has been reduced by the Power of Incubation through various Degrees of Fluidity, paſſing through the different Strata, or *concentric Lamellæ*[1], terminating at length in the required Degree of Subtlety; but even then when it's arrived at the Embryo, this Liquor is comparatively very thick, and muſt be much more highly ſubtilized in the Veſſels and Viſcera themſelves.

[1] The true Chick is that Particle imparted to the Egg by the Cock. But in order to unfold and expand this ſmall Point concealed in the Semen of the Male, the Albumen of the Egg only ſuffices, and the whole Bulk of the Chick is formed entirely from thence from a very ſmall Particle. But the Albumen or white of the Egg is compoſed or made up in the following Manner, which I have always contemplated with Pleaſure. In the firſt Place we meet with the Shell which is of a ſtony Nature or like Mortar, and though ſoft one Day is hard and brittle the next before it is excluded. If this earthy Subſtance be taken off by macerating the Egg in Vinegar, we find immediately under it a tough Membrane, which may be ſeparated from the reſt of the Egg by making a ſmall Puncture in the obtuſe End and blowing into it.

Within the anterior Membrane is contained the Albumen and Yolk, which laſt ſerves for a Placenta to the Fœtus, and in the Center of the Yolk is the Chick itſelf. This Fœtus or incipient Chick is inveſted on all Sides with oval concentric Sacculi, which increaſe in Diameter in Proportion as they are more remote. The Air which is admitted through the Pores of the Shell being rarefied by the Heat of the ſitting Hen, takes up a larger Space, and preſſes upon the included Humours: Thus the Membranes are preſſed ſo as to recede from the obtuſe End of the Egg to which they before adhered, like the Dura and Pia Mater within the Skull; but the Membranes being preſſed, urge the Albumen ſucceſſively through the concentric Sacculi into the Chalazas which are inſerted into the Amnios. In this Filtration or Tranſcolation the Albumen is rendered continually more ſubtle, and is again elaborated in the ſmall Glands of the Yolk, 'till at length it paſſes partly through the Mouth of the Chick (for in the Stomach of the incipient Chick a true Jelly is always found) and partly through the omphalo-meſenteric Veſſels to the Inteſtines, where being elaborated into Chyle, is is abſorbed by the Veins, and ſuffering all the Actions of the Body, is at length converted into Blood, Serum, Lymph, and Spirits. But ſince it is ſo highly ſubtilized while contained in its Sacculi, as to be able to exhale or fly off in an inviſible State, we may readily apprehend how extremely ſubtle it muſt be, when it is perfected and derived into the ſmalleſt Veſſels of the Chick. This Tenuity is obtained by a Degree of Heat which is the moſt favourable to Putrefaction, being much the ſame both in the ſitting Hen and in the Uterus of the gravid Woman.

§. 443.

§. 443. But from this very ſubtle Humour ariſe the firſt tender *Solids* [1], which are very much like Fluids; from which State they paſs through various *Degrees* [2] of Firmneſs, 'till they at length compoſe the moſt ſolid Parts of the Body, as we are taught by *Malpighi* in Eggs, and as hath been demonſtrated with indefatigable Induſtry in Embryo's and *Fetus's* [3] by *Ruyſch*; and which alſo appears from the accurate Order or Courſe of the different Parts themſelves. It is therefore from hence apparent, that the ſolid Parts in their firſt Origin from the Fluids, from whence they are derived, differ only in the *Reſt* [4], *Coheſion* [5], and *Figure* [6] of their Parts.

[1] The Chick which in twenty-four Hours time after Incubation is taken out from the Egg, appears to be no more than a Point, which by a ſmall Puncture with a Needle is reſolved into a red Drop. But yet in that is contained the Brain Cerebellum, Eyes, and all the other Parts which we afterwards ſee produced. In general, the Experiments made upon incubated Eggs demonſtrate, that all the Parts are more fluid as the Animal is nearer its Original; but that they gradually harden, ſo that on the twenty-firſt Day the Bones begin to appear in a perfect State, and within the Space of two Years, in the fighting Cock, they acquire the Hardneſs almoſt of Iron; even every Part of the Body, let it be never ſo hard, was at firſt a ſoft Jelly.

[2] The Thigh Bone is at firſt a thin Lamella, and becomes afterwards a thicker Membrane, at length a thin Cartilage, and then a more compact

Cartilage, within the Center of which the Point of Oſſification begins, and ſpreads itſelf all over the Femur, which is then converted into a hard Bone. There is no Bone in the human Body but what was at firſt a Cartilage, nor any Cartilage which was not before a Membrane, nor yet any Membrane but what was at firſt in the fluctuating State of a Liquor. But barely by Motion and Attrition all even the ſofteſt Parts of the Body are converted into a bony Nature.

[3] *Ruyſch* had a very beautiful Collection of Fœtus's which is now tranſported into *Ruſſia.* And in that incomparable Collection, there are ſeveral ſmall Bodies no larger than Ants, other as large as Peaſe; and from thence there are Fœtus's a great deal larger in Size, and more perfect in their Parts. But even in the leaſt of theſe there are all the Viſcera and Limbs pre-exiſting, or at leaſt there are all the phyſical Cauſes which compleat the human Body; namely, a complicated Canal forming the Heart, with the nervous Syſtem, *&c.* Yet all the Parts are extremely ſoft, and in a fluctuating State; but from that Softneſs they gradually paſs to a more compact State, ſo as even to reſemble the hardeſt Stone, as we ſee in the Teeth, which were themſelves but a little time before a Jelly contained in Cells in the Gums, and receive their Nouriſhment from inviſible Arteries; whereas when they appear through the Gums, they are ſo hard that a Hammer will hardly make any Impreſſion upon them. Even the Hairs which are ſuch ſmall Corpuſcles, are nevertheleſs ſo tough, that if a thouſand of them be twiſted together into a Cord, they will eaſily ſuſtain a thouſand Pounds Weight. It is therefore evident. that the Parts of the Body paſs through various Degrees of

Fluidity and Coheſion, till they arrive at the greateſt Degree of Compactneſs and Hardneſs.

[4] Suppoſe there are three elementary or minute Particles of a Bone, which are not compound, but as ſimple as poſſible, their State will certainly be volatile and fluid, if they are moveable upon each other; but if they reſt or cohere together incapable of Motion they will form a ſolid Body without any other Alteration. Whence it appears that a Fluid differs from a Solid only in Degree.

[5] The Reaſon of the Coheſion of Parts in Bodies is underſtood but by a few. In general, it is a Power by which the Parts of a Body reſiſt Separation from each other: that is, all the Particles of a Body acquire a more powerful Coheſion, in proportion as they are in cloſer Contact with each other, being almoſt infinite when the Contact is the greateſt. If Gold be drawn out into a Wire, or fine Thread, by a ſtrong Machine, it nevertheleſs continues to be the ſame Gold, has the ſame Coheſion and Flexibility; nor will the Power of Coheſion and Ductility in the Parts of the Gold ceaſe, as long as Art is capable of drawing the Wire through ſmaller Holes. Thus wonderful is the Attraction and Coheſion of the Parts of Gold with each other. But the ſame Gold which ſo powerfully cohered before, fly from or repel each other upon making a Diviſion by cutting with a Knife, nor can thoſe Parts be ever conjoined together again: but ſuppoſe it ſeparated into a thouſand ſmall Particles, they may all of them be eaſily reduced into one flexible Maſs by the Force of Fire, cohering as ſtrongly together as at firſt before they were divided. But yet the Fire ſeems to have made no Alteration in the Gold; it only ſeems to have removed the Matter which interpoſed betwixt its ſmall Particles, in ſuch a manner as to

bring their Surface into cloſe Contact; and therefore when the Force of the Fire is abated, the Particles cohere together by their mutual Powers of Attraction, increaſed by their cloſer Contact. For it is this immediate Contact of Parts which is the true Cauſe of their Coheſion, as we are aſſured from numerous Experiments. When a glaſs Lens is poliſhed for optical Uſes, in which Artifice I formerly amuſed and delighted myſelf, we obſerve that the Glaſs moves freely in the Plate ſo long as there is the leaſt Quantity of Emery, Oil, Wax, or the Moiſture of one's Breath interpoſed betwixt the Glaſs and the Poliſher. The Poliſher grows hot from the ſwift turning round of the Glaſs, and if the convex Surface of the Glaſs touches the Concavity of the Plate and Poliſher, they will cohere together in a Moment ſo as to reſiſt Separation. But this Inconvenience never happens unleſs the Machine is become very hot, and the intervening Matter is quite expelled from betwixt the Glaſs and the poliſhing Plate; but when the Coheſion betwixt the Glaſs and the Poliſher is ſeparated, they repel each other, nor will they ever cohere again, unleſs ſo great a Heat and Force of Fire was applied, as is capable of expelling the foreign Matter which was interpoſed betwixt them.

[6] We ſaid before that the Glaſs moſt ſtrongly adheres to the Poliſher, when the Figure of the poliſhing Lens very exactly fitted the Cavity and Shape of the Plate, ſo as to fill it entirely and come immediately into cloſe Contact, whereupon they immediately reſt and become immoveable. From hence we conclude, that there is no Difference in the conſtituent Particles of a Solid and Fluid; but that all the elementary or conſtituent Particles of a Fluid will compoſe a Solid, ſo ſoon as they touch

each other immediately in plain Surfaces, without the Intervention of any other Matter. Thus we ſee that the compotent Particles which we call Fluids, while they are continually moving through the Veſſels of our Bodies, do nevertheleſs become ſolid, when by the Power of Attraction they adhere to the Sides of the Veſſels. A little Ball of Wax does not adhera to the Finger, becauſe it touches but in a ſmall Point, whereas if it be preſſed flat by the Finger, the Surface being extended will cauſe it to adhere very firmly.

§. 444. Therefore ſuch Particles as are now in a fluid State will compoſe or form part of a Solid, ſo ſoon as the Power of *Coheſion* [1] ſhall cauſe them to combine with the other ſolid Particles, by *whatever Cauſe* [2] that Power of Coheſion is produced or increaſed.

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[1] The Particles of the Blood compoſe a Fluid in the Veſſels, becauſe their Points of Contact are continually varied; and therefore the Blood muſt of Neceſſity be fluid, ſo long as the Arteries continue to act upon it; but if the ſame Blood ſtagnates and is urged againſt the Sides of the containing Veſſel, without the Intervention of any aqueous or different Particles, a Solid will then be certainly formed out of the Fluid.

[2] That Attraction is one Cauſe, if not the chief or only Cauſe, apppears probable, inaſmuch as a calcined Bone which retains its Figure being applied to the Tongue, adheres very powerfully to the Skin, ſo that it cannot be pulled off from the Tongue without great Pain and a Laceration of the Part.

§. 445. And this Coheſion of the Parts is beſt produced in a Fibre *already formed* [1], if there are hollow *Spaces* [2] left betwixt the ſolid Particles capable of receiving more Matter in the Place of thoſe Particles which have been waſted; and at the ſame time if there are Particles in the Fluid correſponding in Size, Figure, and *Nature* [3] to thoſe Vacuities; to which add a ſufficient Power or *Vis Vitæ* [4] capable of adapting or thruſting in thoſe Particles into their correſponding Vacuities.

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[1] We do not pretend to determine the Manner in which the Fibre is firſt formed of its conſtituent Particles, we only explain how the Fibre already formed, increaſes or grows from the Aliments as the Animal advances in Age; or how it is regenerated and repaired by Matter, ſupplying the Conſumption or Waſte which is made of all the Parts by the continual Attrition and Motion of them. We ſuppoſe the Fibre to be preſent and already made, without enquiring into its firſt Principles, which are too obſcure to come under our Apprehenſion. The Perſon who enquires after the Manner in which the firſt Fibres were formed in the Animal, falls into the old Difficulty concerning the Egg and the Hen, or the Seed and the Tree, concerning the Priority or Pre exiſtence of which there have been many Diſputes.

[2] Suppoſe one of the ſmalleſt Fibres, compoſed of two ſolid elementary Particles, applied to each other by their Ends; for we cannot here ſuppoſe any Parts to be joined laterally in the moſt ſimple Fibre. Let this Fibre be again extended by the Vis Vitæ which diſtends the Veſſels, upon the

Convexity of which the Fibre is placed in ſuch a manner, as to cauſe the contiguous Particles to recede from each other to a conſiderable Diſtance, but yet not ſo as entirely to deſtroy their Coheſion; there will in that Caſe be formed a void Space betwixt the Particles by the Elongation of the Fibre; in which Space there will be a leſs Reſiſtance, ſo that any Glew or other Matter may eaſily fill up the Interval which was made by the Attrition and Power of the Actions of Life; while the Particles which were abraded, are waſhed out of the laſt formed Intervals, are evacuated by inſenſible Perſpiration, and the other Emunctories (§. 432.) But even the very ſame Humour which abraded the elementary Particles is full of others of the ſame Nature, of which the ſolid Fibres may be compoſed and renewed. Theſe Particles paſſing along the ſmooth Surface of a ſmall Veſſel, will nevertheleſs inſinuate themſelves into any Vacuities agreeable to their Size and Figure, into which they will be forced by that Impulſe of the Humours, which diſtends the Veſſels in a Direction perpendicular to their Axes, while the Impetus of the following Humours will more compact and poliſh the newly ſupplied Parts, ſo as to reduce them to a Level with the Surface of the Veſſel, abrading the ſuperfluous Parts, and ſupplying or filling up all the Intervals made betwixt the elementary or conſtituent Particles. Hence it is, that a true Increaſe of the Body very ſeldom takes place in Adults. For if a Fibre is ſo ſtrong, as to be neither furniſhed with Vacuities by Elongation, nor by an Abraſion of its Parts, there will be no Matter added, but its Surface will be on all Sides ſmooth; but if any Vacuities are formed by the Vis Vitæ, as many Particles will cohere and adapt themſelves as there are Particles abraded.

And, in general, Nutrition never takes place, but where there are ſome Parts abraded or worn off.

[3] The Particles ought to be flexible and tenacious. The red Globules are perfectly ſpherical; but when they arrive at the ſmalleſt Extremities, or Anaſtomoſes of the ſanguiferous Arteries, they aſſume an oval Figure, as *Lewenhoec* has obſerved; in order to which it is neceſſary for them to be flexible, and not endowed with the adamantine Hardneſs. The ſerous Globules alſo retain the ſame Sphericity and Flexibility, but are ſix times leſs than the former; and have ſo much a greater Degree of Coheſion, that they run into long Threads or Chains, which, together, form a ſolid Cake of the whole Maſs, when extravaſated. Yet neither does the Blood nor the Serum nouriſh; for if ſo, only the ſerous and ſanguiferous Veſſels would be ſupported: but that Liquor, which is the immediate Matter of Nutrition, muſt be ſo exceeding fine as to be capable of pervading the very ſmalleſt Veſſels of all in the Body (§. 451). Since, therefore, the Particles of all the nutritious Humours are flexible, and derive their Sphericity from the continual Rotation among other ſimilar Spherules, they will be alſo capable of altering their Figure by the vital Preſſure or Actions of the Veſſels; which is a Property never obſerved, either in the Particles of a Medicine, or of a Poiſon, which are too rigid and inflexible to yield to the Action of the vital Powers.

[4] After a ſmall Globule has entered into a Vacuity, a further Power is neceſſary, in order to break off ſo much as projects beyond the Surface, and to compact and poliſh the Remainder.

§. 446. The true Nutrition of the Solids muſt be therefore performed in the *ſmalleſt* [1] *Veſſels*,

Veſſels[2], of an Aſſemblage of which the larger Veſſels are compoſed; that is, in the Nerves, or in the moſt minute Veſſels, much like unto the Nerves themſelves (§. 302, 440.)

[1] All Parts of the human Body are compoſed of Veſſels before they become callous; but after they have once arrived to that rigid and inflexible State, they are no longer nouriſhed, as they do not admit of any Parts to be abraded: for Nutrition in the full grown Animal is no more than the Reſtitution of thoſe Parts of the Veſſels, which have been abraded by the Motion and Attrition of the Humours flowing through them; and this can take place only in Parts that are vaſcular. But the Veſſels have a twofold Surface, one external, to which paſs the exhaling Vapours which are diſcharged into the larger and ſmaller Cavities of *Hippocrates*; the other internal, tranſmitting the contained Fluid: the former of theſe receives but little Alteration, as it only exhales ſo much perſpirable Moiſture as is neceſſary to prevent the Concretion of its Fibres; whereas the latter ſuffers a conſiderable Preſſure and Attrition from the Impulſe of the Liquor flowing through the Cavity of the Veſſel. Hence therefore it appears, that Nutrition muſt be performed within the Surfaces of the ſmalleſt Veſſels.

[2] The firſt and common Root of all the other Veſſels in the Body is the Aorta; and the ultimate and ſmalleſt Veſſels which are from thence continued ſo as to come within the reach of our Senſes, are the perſpiring Veſſels of *Sanctorius*. But whatever the laſt or ſmalleſt Series of Veſſels may be, it is certain, that they admit of none leſs than themſelves; and that therefore they muſt be compoſed of mere ſimple Fibres and elementary Particles,

ticles, and not be made up of other ſmaller Veſſels, which would be contrary to their Definition. But to prevent their Fibres from growing together, it was neceſſary for them to tranſmit a kind of Moiſture very ſubtle to ſeparate and divide them; for if this Moiſture was not extremely ſubtle, it could not pervade the ſmalleſt Veſſels. It is therefore this moſt thin Liquor which nouriſhes the ſmalleſt Veſſels (agreeable to §. 445); and the true or immediate Matter of Nutrition is ſo ſubtle a Liquor, that it is capable of pervading the moſt minute Veſſels in the Body. But the laſt Series of Veſſels but one are compoſed by an Intertexture of the other ſmalleſt Veſſels, which themſelves are only made up of Fibres, in the ſame manner as if the Intertexture of ſmall capillary glaſs Tubes was convoluted into another Veſſel (§. 445): and the Nutrition of this penultimate Series of Veſſels is carried on by the other ſmalleſt Series of which they are compoſed. Therefore this penultimate Series is nouriſhed as well internally by the Fluid which it conveys, as externally by the more ſubtle Fluid of its ſmalleſt component Veſſels. Again, the antepenultimate Veſſels are compoſed of thoſe laſt mentioned; ſo that Nutrition will be carried on in theſe, as well in the ultimate as in the penultimate, and in the Cavities of theſe antepenultimate Veſſels themſelves: and thus are the larger Veſſels compoſed and ſupported by the ſmaller ones, till we come to the very largeſt of them all, namely, the Aorta. The Aorta is therefore nouriſhed by all the ſeveral Claſſes of Liquors and ſmaller Veſſels in its Compoſition, derived from the Blood in its own proper Cavity; and for this Reaſon that Veſſel diſtributes all the Kinds of Liquors in the Body from the Heart, that the continual Waſte might be repaired, which ariſes from ſo great a Celerity and Attrition of the circulating Blood.

§. 447. Since therefore Nutrition cannot be performed but by a Liquor capable of pervading theſe ſmalleſt Veſſels, I believe you will readily allow that the immediate Matter of Nutrition muſt be the *moſt ſubtle*[1] nervous Juice, or ſome other much of the ſame Nature.

[1] So ſubtle as to be capable of exhaling through the Pores of an Egg-ſhell. It is demonſtrated, that the Body of the Chick ariſes not barely from the Albumen of the Egg, but alſo from the Addition of a more ſubtle Matter; for *Bellini* proves, that the Egg is heavier when the Chick is near being hatched, than it was at its firſt Incubation; and again, that the Chick itſelf breaking out of the Shell is much heavier than the Albumen and Yolk together. This additional Weight muſt therefore have been derived from the Air, or from ſome of the exhaling Vapours of the Hen, during the time of her Incubation; and conſequently it muſt have been ſo ſubtle as to paſs through the ſtony Shell, which is perforated with many ſmall Pores at the obtuſe End of the Egg, paſſing afterwards through the common tough Membrane, and through the ſeveral concentric Lamellæ of the Albumen; at laſt through the two including Membranes of the Colliquamentum, which ſerve for the Chorion and Amnios, and at laſt paſſes with the other Humours under the Form of a Jelly, through the Mouth of the Chick itſelf into the Stomach. Nor does the Egg abſorb only that Matter which gives it the additional Weight during the time of Incubation; but it has inhaling Veſſels, which abſorb a much larger Quantity of Vapours, which are probably

exhaled again. For thoſe Liquors which are leſs groſs than Water eſcape our Senſes. In a chemical Diſtillation of the White of an Egg, there is always ſome Part loſt or exhaled, though the Veſſels be ever ſo exactly cloſed, which Loſs amounts to near a tenth Part of the whole; and muſt have been therefore of ſo ſubtle a Nature, as to eſcape through the Luting and Junctures of the Veſſels.

§. 448. Does it not therefore ſeem credible, that Nutrition is one of the *ultimate* [1] and moſt perfect Actions of Nature? And that in order to the due Performance of this, *all* [2] the ſeveral other preparatory Actions of the Body are required to be carried on in a healthy and regular Manner.

[1] The Albumen of the Egg does not itſelf nouriſh, nor is it immediately converted into the ſolid and fluid Parts of the Chick before it has paſſed through all the ſucceeding Degrees of Attenuation (§. 442.), pervading the ſeveral concentric Lamellæ, which are infinite in Number, and have each their reſpective Albumen, the laſt of them being the Sacculus of the Colliquamentum reduced to the greateſt Degree of Tenuity. We therefore need not wonder, that ſo long an Elaboration and Attenuation of this Humour is neceſſary, in order to render it capable of pervading the moſt minute Veſſels, ſince the Humour appears in its crude State to be ſo thick and viſcid.

[2] Namely, that of paſſing through the Heart, ſanguiferous, ſerous, and other ſmaller Veſſels. Among all the Humours of our Bodies, the red Blood ſuffers the leaſt Action of any, as it only circulates through the ſanguiferous Series of Veſſels;

whereas the Serum undergoes the Action of two Series of Veſſels, namely, that of the ſanguiferous and of their own proper ſerous Veſſels, the Diameter of which is equal to the Semidiameter of a ſanguiferous Veſſel. But the nervous Juice has undergone the Action of all the Series of Veſſels; and therefore ſuch a Juice is the moſt proper to ſupply the Matter of Nutrition, as having ſuffer'd more from the Power or Action of the Parts than any other Liquor. Nutrition muſt be therefore performed in the ſmalleſt Veſſels, which are only capable of receiving the nervous Juice, or a Liquor equally ſubtle. From hence alſo Nutrition appears ta be the ultimate Action of all the Parts and Humours in the Body, for the due Performance of which all the others ought to be rightly diſpoſed: and agreeable to this we obſerve in Practice, that when the primary Actions are defective, this ultimate one of Nutrition is impaired or aboliſhed; as for Inſtance, when the Lungs are decayed.

§. 449. The Chyle therefore may fill the *larger* [1] Veſſels, but cannot immediately *nouriſh* [2] or repair the ſolid Parts of the Body.

[1] As the Aorta ſuffers the greateſt Violence and Deſtruction of its Parts, ſo it is alſo repaired by more Powers than any other Veſſel. But the Veſſels are never obſerved to have large Fragments abraded, but only ſmall Scales, which are capable of paſſing out of the Body with the Urine and perſpirable Matter. But the larger Veſſels have equally the ſame Juices with the ſmaller Branches; that is, the Aorta, as well as the ſmalleſt ſanguiferous Veſſels, have each their reſpective Blood and more ſubtle Juices, that every Particle which is abraded may be ſupplied with others of correſponding Dimenſions. *Lewenhoec*

[2] *Lewenhoec* informs us, that he finds Globules in the Chyle not much leſs than thoſe of the Blood, but of a more rare or lax Texture, as not being compacted into ſo denſe a Maſs (§. 87, 127): the Chyle therefore cannot itſelf nouriſh the Parts, ſince its Globules are too large to enter the ſmalleſt Veſſels, nor does it ever enter into any other than the lacteal Veins, and the lactiferous Ducts of the Breaſt; for it is never found either in the ſerous or lymphatic Veſſels.

§. 450. But when the ſame Chyle has been attenuated by the Force of Reſpiration in the Lungs, where it is intimately mixed, ground together and changed, it becomes fit to enter and paſs through ſome ſmaller Veſſels, and is indeed advanced nearer towards the Matter of Nutrition, from which it is however as yet conſiderably *remote*[1].

[1] There is a conſiderable Alteration or Change thus made by which it differs from the Chyle; for it is not ſo aceſcent, nor does it congeal into a Curd-like Subſtance. But though the alimentary Juice is thus render'd ſomewhat more fluid than the Chyle, one may readily perceive that it cannot as yet be ſubtle enough to be received into the moſt minute Veſſels of the Brain; for if Milk could be in this manner ſo eaſily attenuated, Nature would never have been at the Expence or Labour of cauſing the Albumen in the Egg to paſs through ſuch an infinite Number of Degrees of Attenuation in its Courſe through the concentrical Lamellæ, but that Humour would have been immediately ſent in a direct Courſe into the Veſſels of the Chick.

§. 451. But in time, by the *repeated* [1] Action of the Lungs, Viſcera and Veſſels, the Chyle becomes a mild, tenacious and nutritious Serum, having little or no Taſte or Smell, and congealing with the Heat of Fire, or the Addition of Alcohol Vini, *very much reſembling* [2] the White of an Egg: ſo that it then appears to be ſuch a Fluid, as contains *all* [3] the Qualities or Conditions which we find to be neceſſary by Experience in that Humour, from whence we know all the ſolid Parts of the Animal are *derived* [4] by Incubation only. Thus therefore the Matter is brought a Degree nearer, though it is *not as yet* [5] quite fitted for Nutrition; much leſs is red Blood fit for this Office, nor does either that or the Serum ever enter into the ſmalleſt Veſſels.

[1] The Chyle being received into the lacteal Veſſels, paſſes from them into the thoracic Duct and ſubclavian Vein, from whence it paſſes into the right Ventricle of the Heart and pulmonary Artery; but as yet it has paſſed through none but large Veſſels, having met with no Difficulty from the Smallneſs of their Diameters. But, in the next place, it is urged through the minute Anaſtomoſes of the pulmonary Artery and Vein, and by the Aorta it goes through all the Muſcles and Viſcera together with the Blood, circulating throughout the whole Body under the Denomination of Milk. This Chyle or milky Juice of the Aliment is not converted into Serum within three Hours after a Meal; but if Blood be drawn about that time from a Vein, this Liquor appears floating of a

white Colour upon the Surface. Although the Chyle appears then to have undergone the Action of the Arteries and Lungs, yet it has not been ſufficiently attenuated and changed to form the Matter of Nutrition. But about twelve Hours after a Meal, the lacteal Juice of the Chyle puts off its white Colour, and becomes a pellucid Serum; nor does it evaporate by Heat, but congeals into a ſciſſile Maſs like Leather.

[2] But there is this Difference, that the Albumen is contained in concentric Sacculi, while the Serum of the Blood flows freely through the ſanguiferous Veſſels in a more fluid State; to which add, that the Serum receives ſomething from the Blood itſelf, whereas in other reſpects both the Serum and Albumen are very much alike. Both of them harden by the Addition of Alcohol Vini (§. 226.); and in Diſtillation there is no Difference perceived betwixt the Serum of the Blood and the White of an Egg; both of them afford Phoſphorus by the laſt Degree of Fire, and both of them receive the ſame Changes by Putrefaction; but even the End and Uſes of both are the ſame. The Females of all Animals receive truly the Semen maſculinum into the Serum of their Blood. All Sorts of Animals, whether Fiſh, Fowl, Quadruped, or Inſect, are generated from Eggs, without excepting any, as far as we have been yet able to diſcover. In theſe Eggs the Fœtus's of all Animals are nouriſhed and brought up to that State of Perfection, in which we meet with them at their firſt Appearance in the World; whether the Egg was incubated either within or without the Animal, or brought forward by a determinate Degree of Heat. Almoſt all Birds ſit upon their Eggs, and within the Space of twenty-four Days they hatch their Young, and let them out of the Shells. All Inſects do not ſit

upon their Eggs, but they are hatched by Warmth, as in the Species of the Eruca. But where-ever theſe Eggs are laid, they are always furniſhed with their Albumen, which is in effect a true Serum depoſited from the ſerous Veſſels of the Mother within the Egg, the Cavity of which it fills. But in Birds there is a ſtony Cruſt formed round this Serum, that the Eggs might be preſerved ſafe in the Cold for the Space of three Months without injuring the Fœtus, which may be excluded from the Egg, notwithſtanding it has been kept ſo long, provided it is ſet under the Hen.

[3] This is the true plaſtic Spirit or Moiſture of the ancient Philoſophers, out of which all the ſolid Parts of the human Body are formed as out of a Paſte.

[4] The Albumen of the Egg within the Space of twenty-one Days is, by a determinate Heat, changed into the Subſtance of a Chick. And the like Albumen or Serum is ſo prepared and attenuated by Heat, and the repeated Action of the Veſſels of the human Body, that it paſſes through ſeveral Series of the ſmaller Veſſels in the ſame manner as the Albumen of the Egg is percolated through the concentric Sacculi. There is therefore no Obſtacle againſt the Serum being the Matter of Nutrition, provided it paſſes through the ſeveral Degrees of Attenuation, like the White of the Egg before it forms the ſolid Parts; for from ſimilar Cauſes we may expect ſimilar Effects in Subjects of the ſame Nature. But when the viſcid Serum of the Blood is not formed or generated from the Chyle, as in conſumptive or phthiſical Patients, in that Caſe the whole Buſineſs of Nutrition is aboliſhed. For there are many Veſſels in the Body, which do not admit the yellow Serum of the Blood to enter into them in a natural State; as we obſerve in the

uriniferous Ducts, the pellucid Lymphatics, the lactiferous Ducts of the Breaſts, *&c.* in which we never find any Serum capable of hardening with Heat, or Alcohol of Wine: but the Humours of thoſe Ducts are groſſer than the Serum, and there are many others not much more fluid. When the Arm of a healthy Perſon is placed in a clean glaſs Veſſel in the Summer-time, the Vapours exhaling from the Skin will be condenſed into Drops adhering to the Sides of the Glaſs (§. 426.), and will again evaporate from the Glaſs without leaving any Reſiduum or groſs Matter behind; and therefore it contains nothing of the Nature of Serum or Oil, for either of theſe leave a Spot behind them continually, and the Serum congeals into a hard Jelly by the Heat of boiling Water without evaporating.

[5] The Serum of the Blood has not indeed acquired all the Properties of the nutritious Humour; but it muſt firſt undergo a very high Attenuation, before it can become ſufficiently ſubtle to perform the Office of Nutrition. Thus alſo the Albumen of the Egg does not immediately nouriſh, but that Humour which is prepared from it, and ſent into the Sacculus of the Colliquamentum, being much finer than the Albumen unprepared.

§. 452. But as the *Heat* [1] of Incubation, ſo the Actions of the Viſcera and Veſſels, aſſiſted by the ſame Heat ariſing from the vital Powers, introduce divers Changes continually in the healthy circulating Serum of the Blood, till at length ſome Part of it becomes ſo *ſubtle* [2] a Humour as is required for the Buſineſs of Nutrition, in order to repair immediately that which is waſted; and it is this laſt moſt ſubtle Humour, prepared from the Serum of the Blood, which at length becomes the true and immediate Matter of Nutrition.

[1] In the Metropolitan City of *Egypt*, at this Day termed *Grand Cairo*, Eggs are hatched in Ovens by the Application of a certain Degree of Heat; but if that Degree of Heat is too much exceeded, the Eggs come to nothing. So alſo it is with us; for our Bodies are not nouriſhed when the Blood is kept in too great a Heat.

[2] From the groſs Chyle is formed another which is more ſubtle, in the Form of a Liquor which is converted into Milk, which Milk is converted into Serum, and that Serum into Blood; but the Blood itſelf is again reſolved into Serum, and that Serum into Lymph, which Lymph is attenuated into ſeveral Orders of Liquors ſtill much more ſubtle. In the ſame manner is the Albumen of the Egg attenuated and ſucceſſively propelled through the concentric Sacculi, till it at length enters the Colliquamentum in the Form of a moſt ſubtle Liquor through the Chorion and Amnios. In both theſe Caſes the thing is the ſame, though we are not capable of enumerating the ſeveral Degrees of Tenuity in the Particles either of the Albumen or Serum. But how ſubtle a Liquor may be prepared from the Aliments, we are taught by the Inſtance of the Alchemiſt; for the good old Man had read, *From thee, O King, is drawn the Matter, my Breath is my Life.* Hereupon he proclaims himſelf victorious, and taking a large chemical Veſſel breathes into it for ſo many Days and Nights, until a large Quantity of Liquor was collected. But ſtill it remained for him to fix this volatile Mercury of Life, but he could never find himſelf able to reſtrain the Fugitive from evapo-

rating immediately upon feeling the Heat; to do this he tortures his Mind and Body to no Purpoſe, till being overpowered with Labour and Fatigue, he finds himſelf to have wrought the great nothing. Theſe Men have certainly a happy Stock of Fooliſhneſs, and are fit to furniſh out Experiments to better Philoſophers, who never fatigue themſelves with ſo much Labour to ſo little Purpoſe. Certain it is that from ſuch groſs Food and ſuch thick Chyle and Blood, are formed Juices in themſelves ſo extremely volatile, that they fly off into the Air ſpontaneouſly, in the ſame manner as the Albumen of the Egg, which has not been fœcundated, is ſo highly attenuated by the Heat of Incubation, that after Putrefaction it exhales through the Shell. Even a new laid Egg continually expoſed to the warm Air becomes lighter every Hour, and the Cavity at the obtuſe End by degrees enlarges and occupies the whole Egg, till at length all the Humours exhale through the including Shell and Membranes, leaving nothing behind but a ſmall Quantity of Earth. If we ſubſtitute an Egg to a chemical Analyſis, all the Parts which are oily and watery will ariſe by the Heat of the Fire, leaving only a black Sediment remaining, which after Calcination affords a ſmall Quantity of a white Earth.

§. 453. But how ſimple, *inſipid*[1], and inodorous this nutritious Humour is, we are taught by Fire, Putrefaction, and Chemiſtry; for there is nothing left after theſe Proceſſes more than a *very light*[2] and *ſimple Earth*[3].

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[1] The more any one of our Humours is elaborated and ſubtilized, the nearer it approaches to

the Nature of Water; but yet is there a conſiderable Difference betwixt them and real Water; for that laſt diſſolves inſtead of nouriſhing the Parts, nor can a Man ſupport his Life with mere Water, but he will ſoon be deſtroyed. There are Inſtances of Captives which have faſted for the Space of twenty Days when they have been ſupplied with Water, whereas they could not have ſubſiſted ſo long as nine Days without Water; nor yet does Water nouriſh. But the nutritious Fluid differs from Water inaſmuch as it is generated from the Serum of the Blood, which alone has the Property of hardening with Heat among all the Humours of the Body: for the Chyle, Saliva, Semen and aqueous Humour of the Eye do not thicken like the Serum of the Blood (§. 246.); but this Property of coagulating is a Characteriſtic of the nutritious Humours. After I had diſtilled the White of an Egg, there remained in the Bottom of the Veſſel almoſt one tenth Part of the Conſiſtence of Horn, while nineteen Parts were drawn off in the Form of Water, but ſomewhat different from common Water, ſince it would kill Quickſilver, which Rain-water will not; for which purpoſe it was therefore eſteemed a Secret by *Helmont* and others. There is therefore a certain plaſtic and coheſive Property in the Serum of the Blood, and in the White of an Egg, which is not found in Water. Not that I would have it ſuppoſed that the Serum itſelf nouriſhes, but that from the Serum attenuated by the vital Powers is formed a very ſubtle aqueous Liquor, in the ſame manner as the Chyle is by the vital Powers converted into Serum, which hardens with Heat; and that the Serum at length nouriſhes, after it has been ſo highly attenuated as to become perſpirable. And this ſecond Kind of Attenuation which the Serum receives renders it unalterable; for the Serum cannot be hardened after it has been once attenuated in this manner; nor can the Albumen of the Egg be indurated by Alcohol Vini after it is become ſemiputrid by Incubation.

[2] Which are altogether volatile. An old Man of eighty Years of Age has perhaps changed his Bones a hundred times, receiving new Nails and Fleſh, while the old Bones, Fleſh, Nails, *&c.* have been ſo wore away and evacuated from the Body inſenſibly, ſo as to leave nothing fixed; and this not without Surprize to thoſe who are ſkilled in Chemiſtry, who ſee that by a moderate Heat thoſe Parts are volatilized, which remain fixed even in the moſt intenſe Fire. Hence *Helmont* rightly obſerves, that unleſs the ingeſted Aliments are attenuated and volatilized, into a ſubtle Dew, the Perſon will in a little time be reduced to a Maſs of Earth. For the Aliments by which we are nouriſhed, are repleniſhed with earthy Matter, with which we ſhould be in a little time ſtuffed up, if it was not to be volatilized and inſenſibly diſcharged. Theſe ſolid earthy Particles or Elements being reduced to a great Degree of Subtlety, are alone capable of pervading the ſmalleſt Veſſels, and of affording the immediate Matter of Nutrition.

[3] The ſolid Parts of the human Body are made up of mere Earth, which is neither reſolvable nor mutable in Water, Fire, or Air; but Water renders theſe ſolid Parts more compact: Earth is the Baſis, Water the connecting Glue, and from both is formed the ſolid Fibres of the human Body.

§. 454. But we find that this ultimate Matter (§. 452.) can be only prepared by paſſing through all the Degree of Attenuation (§. 449 to 453.)

§. 455. But the ſame nutritious Humour may become *acrimonious* [1] by a too ſwift and frequent Circulation, or by being too long retained, whence its Fluidity may be deſtroyed, and its Subſtance thickened, its oily Parts being drawn off or exhauſted, and the Salts ſharpened, from whence it becomes unfit for this Purpoſe of Nutrition and Secretion.

[1] All Animals both Male and Female are nouriſhed with Milk; and even in the Breaſts of new born Infants of both Sexes, as well as in grown People, there is Plenty of Milk to be found. But this Humour does by continual Heat and Motion become acrimonious, notwithſtanding it is at firſt mild, or ſweet, and anodyne: for from Milk is generated Serum, and Serum merely by too long a Circulation becomes acrid and fœtid, evacuating itſelf by Urine, which alone by Reſt and Heat affords the moſt acrimonious Salts. By mere faſting alone all the Humours become acrimonious, as *Tſchirnhauſen* has rightly obſerved (§. 66.); and there are many Inſtances in which the Saliva has bren acrid enough to corrode the Gums, and the Urine the Bladder; for while the more ſubtle Parts are exhaled, the oily Parts are waſted or conſumed, and the Salts rendered more acrid.

§. 456. From hence therefore we ſee the Neceſſity there is for the Blood and Humours to be repleniſhed with *new Chyle* [1], from the repeated Ingeſtion of ſolid and fluid Aliments, in order carry on the Buſineſs of Nutrition.

The Neceſſity for Food to be continually taken into the Body, is not in order to keep the Veſſels full; for in the dead Bodies of the human Species, as well as in thoſe of Brutes, the Veſſels are found full of Blood, and contain ten times as many Juices as there are found in the Body of a tabid Perſon. But in a Man who has ſuffered Hunger for a long time, all the Humours are attenuated and rendered more acrimonious by their continual Heat and Motion, by which they incline to Putrefaction, and occaſion Thirſt, Fevers, Madneſs, and at length Death itſelf; and in the dead Bodies of ſuch, the Brain appears flaccid, and in a manner deſtroyed. Namely, becauſe the freſh Chyle is wanting, which by its gentle aceſcent Quality might temperate the putrefactive Nature of the Humours; and in all Animals, without excepting the moſt fierce, the Chyle is the mildeſt Humour of any in the Body, as it ought to be to temperate the acrid Humours, dilute and correct them as they are corrupted and waſted by the continual Actions of Life, more eſpecially as the Animal is more fierce and prone to Wrath. There is alſo the ſame Neceſſity for Drink to waſh out the putrid Particles from the Blood and Humours, which if retained in the Habit would injure or deſtroy the tender Fabric of the Brain and Cerebellum.

§. 457. But for the Manner how and the Cauſes from whence Nutrition is performed, we may ſufficiently underſtand theſe from what follows.

§. 458. The Humour being propelled ſtrait forwards through a *full* [1], conical or cylindrical *Veſſel* [2], either elaſtic or rigid, paſſes from a larger Capacity to a leſs; and from the Reſiſtances oppoſed to its Motion, it will endeavour to extend or dilate the Sides of the Veſſel according to its *longitudinal* [3] Axis. And this happens throughout the whole Body, except perhaps in the Veins and *cavernous Receptacles* [4].

[1] All the Veſſels of the human Body are flexible; and even the Bones themſelves were at firſt mere Membranes pervaded with flexible Veins. And beſides this all the Veſſels are full even unto their laſt Extremities, as we are convinced by the Microſcope (§. 213.).

[2] It matters not what Figure the Veſſel be of, provided it be full and the Liquor flows through it with a certain Velocity; for then the Liquor with which the Veſſel is already filled, will reſiſt the Entrance of the next which follows, which conſequently cannot paſs into the Tube unleſs it removes or thruſts forward the preceeding Liquor from its Place. That Liquor therefore which is projected from the Heart into a full Veſſel ſuffers the Action of a Preſs, betwixt the Force of the Heart urging behind, and the reſiſting Blood before, which it is obliged to move forward with the Reſiſtance from the conical Figure of the Artery. Therefore the whole Force which the Blood receives from the Heart will be returned upon the Sides of the Veſſel, as *Herman* demonſtrates. But as much as the Sides of the Veſſels are diſtended with the Blood, ſo far are they removed from the internal Cavity; ſo that when the Blood preſſes upon the Sides of the Artery, and is again repelled by the ſame, it exerts its Force according to

the Length of the Veſſel, endeavouring to go forwards, and by that means to elongate the Veſſel itſelf.

[3] For ſince the Veſſel is conical, all the Particles of the Humours which are propelled by the Force of the Heart in Lines parallel to the Axis of the Artery, will ſtrike directly upon its converging Sides, and by removing every Point of the flexible Veſſel, they will endeavour to elongate the ſame, unleſs the Canal reſiſts with an infinite Force. But there are no ſuch infinitely reſiſting Veſſels found in the healthy human Body, or if there were ſuch, the Circulation of the Humours would in them be certainly ſtopped. Since therefore the Veſſels give way to the Impetus of the Humours, they muſt of neceſſity be elongated.

[4] Namely, in the Veins the Humours flow from a narrower to a larger Part of the Veſſel continually into larger Receptacles, and therefore in ſuch Veſſels the Sides are preſſed only by the Weight of the Humours: nor do they endeavour to elongate the Veſſels, ſince they find a ready Paſſage free from Reſiſtance towards the Heart, which being contracted and emptied forms a Vacuity for the Reception of the ſucceeding Blood, which therefore runs freely from the Veins into the right Sinus, Auricle, and Ventricle. Hence therefore the two Ounces of Blood which are propelled from the Arteries into the Veins at every Syſtole, do not dilate the latter; and therefore there ſeems to be little or no Friction of the Blood in the Veins, though their Sides or Membranes ſuffer ſome Attrition, as well from the Blood as from the Motion of their ſmall component Arteries; and theſe being of the ſame Nature with all the other Arteries ſuffer a like Attrition and Friction from the Blood.

§. 459. But by this Force, though very *ſmall* [1], being continually repeated, the Veſſels will be elongated gradually and inſenſibly, and in their Elongation will be more and more *extenuated* [2], and that even in a ſhort Space of *Time* [3].

[1] This Force is not indeed ſo exceeding ſmall, ſince it is equal with the Motion with which the Blood circulates, and by which no ſmall Degree of Heat is produced in the Blood. But even ſuppoſing this Force to be the leaſt imaginable, it might nevertheleſs by its repeated Action produce the ſame Effect as the greateſt Force acting in but one Moment of Time. For the Force which will elevate one Grain being repeated ten thouſand times will raiſe more than a Pound Weight. When a Drop of Liquor falls upon the Surface of a poliſhed Marble, it may produce no ſenſible Effect or Abraſion in the Stone though repeated many thouſand times; but by a continual Fall of Drops for many Years upon the Surface of ſuch a Stone, there will be an Excavation formed equal to what an Iron Inſtrument could produce with a greater Force in a ſhorter Space of Time; whence it is evident, that by a Repetition of ſmall Strokes, the ſame Effect may be produced as by a greater Force in a ſhorter Space of Time. But the Power of Liquors in diſtending the Sides of the Veſſels, and in elongating them according to their Axes, is exerted as often as our Arteries vibrate, namely, thirty-ſix hundred times in an Hour, or eighty-ſix thouſand four hundred times in a Day. So that if the Force applied at one Inſtant to extend the Veſſels is but ſmall, by collecting together their Sums agreeable to the time, it will appear very conſiderable.

2 All the Veſſels are thickeſt and ſtrongeſt towards the Heart, and become thinner as they recede farther from that Muſcle, except only the Veins, which at their Sinus's in the Liver and Heart are covered with a muſcular Membrane. The Aorta, which is ſo extremely thick at the Heart, is ſo very fine and tender in its ſmalleſt Extremities which exhale the perſpirable Matter of *Sanctorius*, that there is no great Difference betwixt the Coheſion of thoſe Veſſels and many of our Fluids. And the more any Artery is ramified into ſmall Branches, the more thin and tender are the Sides and Membranes of thoſe ſmalleſt Arteries. But the Impulſe of the Blood propelled from the Heart into the Aorta, is continued from thence to the ſmalleſt Extremities of the Arteries, and even into the ultimate Pores, which are formed in part by the membranous Extremities of the Arteries, whether they terminate in Veins or excretory Ducts; for theſe laſt giving no Reſiſtance, may be looked upon as Vacuities; and thus the Extremities of the Veſſels will be extenuated in ſuch a Manner, that approaching near to a Diſſolution, they aſſume almoſt a fluid State. But all the Extremities of the Arteries are open, and may be therefore looked upon as Membranes cut ſhort off; hence therefore the Veſſel will be diſtended and elongated moſt in theſe Extremities.

3 The Elongation ſeems to be manifeſtly the largeſt in the ſmalleſt Veſſels. The Beard being cut off very ſpeedily grows again; ſo that in an *European* Man who ſhaves once a Week, the Beard will acquire the ſame Length next Week as it had before, and thus there will be fifty-two times as great a Length of the Beard cut off and renewed again within the Space of a Year. But this great Length of Hair which is ſhaved off from the Beard, much exceeds the Length which it would

acquire without ſhaving; for we know that *European* Men who follow the Cuſtom of the *Turks* in *Aſia*, have their Beard grow to their full Length within the Space of ſix Months, beyond which they grow no longer; from whence it manifeſtly follows, that the Hairs grow faſter by cutting or ſhaving, ſo that the Veſſels meeting with leſs Reſiſtance are more eaſily and ſpeedily elongated by the impelled nutritious Matter. For there is not the leaſt room to doubt that the Beard grows, or is thruſt out by the Force of the Heart and Arteries, which move all the Humours, and extend all the Fibres. The Stag which every Year caſts off his Horns, has them again renewed annually, but always with one Branch more than before, ſo that from the Number of Branches one may determine the Age of the Creature. In this Animal, after the Horn is caſt off, there remains in its place a ſoft Tumor full of Blood, which is reckoned a Dainty at the Tables of Princes. Theſe Tubercles turn into Horn by the time of the third Month, and in the ninth Month they are grown to their full Hardneſs; but all this Increaſe and Compactneſs of the Horn reſulted only from the repeated Strokes of the Heart and Arteries. It is therefore evident enough with what a conſiderable Force the Humours are propelled through the ſmalleſt Veſſels of Animals.

§. 460. From hence therefore the ultimate Extremities of the Veſſels, as being the thinneſt and *leaſt compact* [1], will be *always* [2] neareſt to a State of Diſſolution.

[1] All the Veſſels of the human Body are compoſed of elaſtic Fibres or Threads; but every elaſtic Thread is weaker in proportion as it is ex-

tended by a greater Force, and approaches nearer to a Diſſolution: for the Strength or Reſiſtance of any Chord by which it reſiſts Rupture, reſides entirely in the mutual Attraction of its Parts. When a Chord is extended longitudinally, its conſtituent Particles recede mutually from each other, but yet their Coheſion is continued as long as they remain in Contact; and upon removing the extending Force, the whole Chord contracts to its former Length: but if you continue the Extenſion longer, ſo as entirely to remove the Contact of the Parts, the String will then fly in pieces towards oppoſite Directions. This Experiment may be tried in a ſingle Hair, which will ſuſtain an Ounce without breaking. Every ſimple Fibre ſeems to be compoſed of ſolid elementary Particles, diſpoſed in the ſame Order as Maſons or Bricklayers build up the Walls of a Houſe. Suppoſe then we have a Thread of ſuch a Thickneſs, as to conſiſt of four Rows of elementary Particles placed parallel to each other, ſuch a Thread will have a powerful Coheſion: and let the ſame Thread be extended, till it is no thicker than two Rows of thoſe Elements, the Coheſion will then be leſs; but if the Diſtraction is farther continued until the Thread is no thicker than the Diameter of one Chain of alimentary Particles, that Thread will then be the neareſt it can to a State of Rupture, which immediately follows upon ſeparating the Coheſion of any two in the ſingle Row of elementary Particles.

[2] Hence it is, that when the Impulſe of the Humours is increaſed againſt the Veſſels in all Diſeaſes, the Cuticle ſcales off; and this not all at once, or at any State or Seaſon of the Year, as we ſee in Serpents, but almoſt continually or every Moment of Life, there are Scales caſt off from the Cuticle. For the Scarf-Skin appears to be the

ultimate Extremities of all the ſmall Veſſels of the Skin (§. 423.) Even by rubbing the Hands together, there are always more or leſs of theſe Scales abraded from the Cuticle, as there is likewiſe by waſhing the Hands: but theſe Scales are truly the Extremities of the cutaneous Veſſels; and if you continue the Abraſion farther, it excites great Pain, and the Blood follows.

§. 461. Thus therefore the ultimate Extremities of the Veſſels are render'd ſo extremely thin and weak, that they differ but little from the Coheſion of the *Fluids* [1].

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[1] There is nothing at all incredible in this Propoſition. For the largeſt among the ſmalleſt Veſſels, namely the ſanguiferous, appears to be ſmaller than a Hair of the Head, where it joins with the incipient Vein, and the Microſcope magnifies it to the Size of one's Finger. Therefore the largeſt among the ſmalleſt Veſſels is thirty times leſs than a Hair of the human Head, which certainly is the leaſt Proportion betwixt a Hair and the Finger, to the Bulk of which the ſame Microſcope magnifies the Hair. But the exhaling Veſſels are ſtill much ſmaller by many thouſands of times, the Number of which no one will pretend to determine. But theſe exhaling Veſſels are not only ſeated in the Cuticle, but alſo in the Cavity of the Lungs, Thorax and Abdomen, as *Hippocrates* obſerves. But theſe ultimate exhaling Veſſels are compoſed of more than one or a few, perhaps a thouſand of the ſolid elementary Particles. It is therefore highly probable, that one elementary Particle conſidered alone, is of equal Subtlety with the Particles of a Fluid; and when once abraded from its Veſſel, it

may fluctuate as eaſily after, as it did before when it was Part of the Chyle.

§. 462. Whilſt therefore this Motion of the Humours (§. 458.) is perpetually continued forward by the Impulſe (§. 458, to 462), theſe two Conſequences muſt neceſſarily follow; namely, in the firſt place, that the ultimate Particles of theſe ſmalleſt Veſſels being abraded, will again aſſume as it were the Form of a fluid Humour, in whatever Part of the Body they are ſeated; and in the next place, that the ſmall Particles which compoſe the leaſt Fibres will be ſo ſeparated from their mutual Coheſions, as to leave *intermediate Vacuities* [1] betwixt thoſe Parts where they before touched and cohered; and this likewiſe happens in every Part. Thus theſe two Conſequences are continually produced in every Part of the Body at one and the ſame time, as long as Life continues; but this more eſpecially in thoſe Parts where the vital Powers are the ſtrongeſt, and in thoſe Bodies addicted to the moſt violent Actions and Exerciſes.

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[1] When one elementary Particle is abraded and evacuated out of the Body, another ſucceeds, and fills up the Space of the former; and this in a continual Succeſſion, one Particle thruſting forward another, and filling up the void Space which the other occupied; and thus will there be a Succeſſion of elementary Particles, from the Heart even to the Ends of the ſmalleſt Arteries, capable of repairing the internal Sufaces of the Veſſels, and at the ſame time the Elements will be ſo changed and

compacted, as to leave no Inequality in the Surfaces of the Veſſels. But this is performed as well in the exhaling Arteries, as in thoſe which open into the Veins; for the Veins may be in a manner conſidered as void Spaces, into which the Extremities of the Arteries are inſerted.

§. 463. But the ſame Humour which both abrades and elongates (§. 462.) contains likewiſe a large Stock of ſuch Particles as are of the ſame Nature with thoſe abraded or deſtroyed; and theſe are conveyed and applied to thoſe very Interſtices by the Impulſe of the ſucceeding Humour, from whence aroſe the Deſtruction of the Parts; and the ſucceeding Matter being thus intercepted into the Vacuities, is, by the Impulſe of the ſame Humour, fixed and formed ſo as to adhere equally firm like the former: for the Matter, the Preparation, and the Application thereof, with the moving Power in the nutritious Humour, always remains *the ſame*[1]; whence follows an *exact*[2] Reſtitution of the loſt Parts, ſo as to maintain the Solids in their former State, that is, to continually nouriſh and preſerve them.

[1] But the Humours of the Body remain equally unaltered, ſince the Place of one Particle, which is abraded or exhaled, is ſupplied by another; ſo that the Elements both of the Solids and Fluids continue the ſame both in Number and Diſpoſition, and only the individual Particles are altered. This perpetual Change of new Particles in the room of the old Elements continues as long as Life remains, and the vital Powers continue ſtrong

enough

enough to convert the ingeſted Aliments into our own Nature; but when that Power ceaſes, the Reſtitution of what is loſt or waſted by the Actions of Life fails, the Aliments retain their crude Nature, or they overpower Nature, as *Hippocrates* expreſſes it, and Death itſelf is near at hand.

[2] For as much new Matter is applied in proportion to the Interſtice or Vacuity, which is formed by the abraded Particles; while at the ſame time the rough or ſuperfluous Extremities of the Particles which project beyond the Surface of the Veſſel, are abraded and brought to a Level without leaving any Deficiency (§. 445), ſince the Veſſels are, in a natural and healthy State, always full of healthy and nutritious Humours.

§. 464. But in this the wonderful Wiſdom of the *Architect* [1] is apparent, in contriving that the ſame Cauſe which inevitably deſtroys, ſhould alſo at the ſame time, and by the ſame Means, repair the decaying Fabric of our Bodies; and that likewiſe from the ſame Cauſe the Supplies ſhould be larger in proportion, as the Waſte is greater; and that thoſe Parts which are firſt decayed by the Actions of Life, ſhould be always the firſt ſupplied and repaired with the nutritious Matter.

[1] This Artifice is worthy to be admired by all Mortals, and is not to be matched in any other Machine whatſoever, namely, that the ſame Force which abrades ſmall Particles or Scales from the animal Solids ſo as to form Vacuities, ſhould itſelf and at the ſame time repair the loſt Subſtance with ſuitable Matter. Thus Life itſelf deſtroys our Bodies, as well as it repairs them; for Life is as well

the Cauſe of the Circulation in the Humours, as of the Deſtruction and Reparation of the Solids; the more violently we exerciſe the Body, the more do we wear off from it, and the greater are the Repairs made to the Solids.

§. 465. It is then evident, that the more minute or *tender* [1] thoſe Veſſels are, and the younger, as alſo the nearer they are to the moving Cauſe, ſo much the more eaſily may they be elongated, diſtended, abraded, and again renewed.

[1] So much more eaſily are they elongated, abraded, and repaired. For ſince the Particles are applied to the Veſſels with a ſmall Force, they are likewiſe abraded with but a ſmall Force; nor can the reſiſting Forces in the Particles be greater than the renovating Powers. The ſmaller the Thread or Chord, the more eaſily is it extended; for a ſilk Line or Thread is much more extenſible than a Rope, and a Chord which ſounds a high Note is more eaſily ſtretched than a thicker String which ſounds the Baſe. But the greateſt Reaſon why Nutrition is the moſt copious in proportion while the Solids are young and more flexible, is, for that in a Fœtus or Infant there are the greateſt Number of Veſſels, which diminiſh their Number in proportion as the Animal advances in Years: for that internal Force by which the larger Veſſels are diſtended, ſo compreſſes and flattens their Membranes, that at length they become callous, and grow together. Thus we may eaſily conceive that a Veſſel, whoſe Membranes are compoſed of a hundred Fibres, will reſiſt more than another whoſe Membranes are compoſed of a hundred ſmall Veſſels in-

ſtead of ſimple Fibres. But the diſtending Cauſe is always the ſame, namely, the Force of the Heart; and therefore the ſtronger Veſſels will be leſs extended than thoſe which are more flexible: and hence it is, as *Ariſtotle* formerly obſerved, that the Heart has required its full Magnitude by the twentieth Year of Age; whereas the reſt of the Body grows even to the thirtieth Year of Age, ſo as to render the ſlender and comely Youth, a thick, ſquare, and ſtrong Man. For in the Heart the Veſſels are the ſtrongeſt, and from thence they become gradually weaker, as they are more remote, or recede farther from the Center of the vital Powers, the Heart itſelf.

§. 466. Hence therefore our Bodies *grow more*[1] in proportion as they are nearer to the Birth.

[1] A human Egg weighs perhaps about ſix or eight Grains in eight Days time after Impregnation; but all that time almoſt the whole Bulk of the Egg ariſes from the Membranes and Humours; whereas the ſmall Animalcule which forms the Man is ſcarce one thouſandth Part of the whole Egg; and yet from ſo ſmall a Stamen within the Space of nine Months is formed an Infant weighing ten or a dozen Pounds, the Difference is as 1 to 9216000. But if the Body of an adult Perſon was to grow after that Rate, his Bulk would increaſe every Year Millions of Millions of times larger than before; ſo that in a few Years he would exceed the Earth itſelf, which would not be capable of ſuſtaining him; and he would equal the Stature of the Fiſh to which the *Jews* report the *Meſſiah* gave a whole Nation for a Meal. But even the firſt Year after the Birth the Infant grows not ſo faſt as before,

and ſtill leſs the ſecond Year than the firſt, and ſo on diminiſhing to the twenty-fifth Year, when the Increaſe is but a very few Ounces. But what ſeems very wonderful in the Growth of the Fœtus is, that it ſhould be able to diſtend the Uterus from whence it receives its Juices: namely, the female Uterus appears ſo compact, that it can ſcarce be diſtended by Flatus; whereas if a ſmall Ovum no larger than a Peppercorn comes into its Cavity, the Uterus will be ſo extended thereby as to contain the Quantity of eighteen Pounds, to which Quantity the Ovum is enlarged. But yet there is nothing in the Ovum but what is received from the Uterus; and therefore it ſeems wonderful that the Uterus itſelf ſhould be expanded by the very Humours which are derived from its own Body: but all this Force muſt ariſe from the little Heart of the Fœtus, however ſmall, ſince there is no other Cauſe of Extenſion in Animals but that of the Heart only.

§. 467. But while this Action (§. 458.) is carried on, the larger Veſſels are more extended by their contained Liquors; but at the ſame time the ſmalleſt Veſſels of which the larger are compoſed will be compreſſed, deprived of their Juices, and concreted *together* [1]; from whence follows *ſtronger Fibres* [2], but at the *Expence* [3] or Loſs of the ſmalleſt Veſſels. The Strength of the Fibre reſulting from the Coheſion of the conſtituent Elements or Particles, remains the ſame as if the Fibres were each ſeparate: but the Power of a Membrane is increaſed by the Coheſion of the Fibres; ſince the ultimate Particles or Elements in one of the ſmalleſt Membranes have twice the Contact and Coheſion which they have in a ſimple Fibre. Alſo the elementary Particles of a Fibre, formed by the Coheſion of two others, will be three times as ſtrong as the Power of each of the two Fibres alone; and thus likewiſe in every ſimple or ſmalleſt Veſſel: and the elementary Particles will cohere four times more ſtrongly in a Membrane formed of the ſmalleſt Veſſels compreſſed together into ſolid Fibres, *&c.*

[1] Concerning this ſee what has been ſaid upon the Subject, in the Beginning of our *Practical Aphoriſms.*

[2] The Reſiſtance of a ſimple Fibre againſt the Impulſe of a diſtending Fluid, may be conſidered as one Power ariſing only from the mutual Attraction of Coheſion betwixt the two Elements; but if to that Fibre another is applied laterally, there is a new Force produced, namely, that which reſults from the mutual Attraction of the two Fibres in contact with each other's Surface; and if again a third Fibre be added, the Force will be increaſed to the Moment of three, ſince the third Fibre attracts with the ſame Force as the ſecond. If now theſe Fibres are formed together into a ſmall Veſſel, their Power will be augmented to the Moment of four, by increaſing the Coheſion of the Fibres, which being cloſed together by the Sides of each other compleat the Cylinder: and if ſeveral ſuch Veſſels are conjoined together, a fifth and a ſixth Increaſe of the Power of Coheſion will ariſe, which will be ſtill multiplied in proportion as the Membranes and Veſſels are more compounded of other ſmaller Veſſels and Membranes, by the contiguous

Surfaces of which the Coheſion is increaſed. For it is evident, that the Coheſion of the elementary Particles, each of which do not ſeparately cohere more powerfully, may nevertheleſs be increaſed to an immenſe Degree only by increaſing the Coheſion or Contacts of the Membranes and Veſſels which they compoſe. If again the oppoſite Sides of a cylindrical Veſſel cohere together, the Strength of that Veſſel will be much increaſed only from augmenting the Contact of the plain Surfaces; and if one Veſſel adheres to another, or ſeveral Veſſels to others adjacent, the Strength of the Body will by that means be greatly augmented. Hence therefore it is evident, that merely by the Force of the vital Actions, the Strength may be immenſely increaſed, and the Veſſels themſelves diminiſhed; for the Number of the ſmall Veſſels depends on their being pervaded by the Humours, and the Strength of them reſults from increaſing their Contacts.

[3] The Heart is the Principle of all Motion in the animal Machine, which Motion is firſt received from thence by the Aorta; and the Coats of that Artery appear to be compoſed of innumerable ſmall Veſſels. Now when this Artery is extended by the Force of the Heart, the Veſſels which compoſe its Membranes are compreſſed and concrete together; and in this Manner is the Number of the ſmaller Veſſels in the human Body diminiſhed continually, while the Strength of the larger Veſſels is increaſed.

§. 468. So that the Parts which were formerly Veſſels in us, do in Proceſs of Time by inevitable Neceſſity, turn into mere hard *Ligaments* [1], as we are aſſured by Obſervation: for the Sutures of the Cranium, for Inſtance, are quite obliterated in extreme old Age, which is an evident Sign of the Loſs of a great Number of the ſmall Veſſels.

[1] Some of the largeſt Veſſels in the Fœtus are doubtleſs the umbilical Artery and Vein, with the Canalis venoſus hepaticus, and the Canalis arterioſus betwixt the pulmonarry Artery and Aorta: but yet theſe Veſſels however large do nevertheleſs concrete and change into round impervious Ligaments ſoon after the Fœtus is delivered from its Mother.

§. 469. Thus at length the Humours concreting, we have reaſon to *believe* [1], that the ſmall Veſſels coaleſce or grow together with them from the ſame unavoidable Neceſſity.

[1] For the Blood of the umbilical Arteries does not return into the Courſe of the circulating Humours; but forming a polypous Concretion, it grows together with the Sides of the Veſſel into one ſolid compact Chord.

§. 470. Therefore by the *Concurrence* [1] of theſe Cauſes (467, 468, 469.), the Strength, Thickneſs, Hardneſs, and Rigidity of the ſolid Parts is produced.

[1] Namely, the Concurrence of three Cauſes: 1. The ſimple Combination of the elementary Particles into larger Fibres and Membranes; 2. The Expulſion of any foreign Fluid interpoſed betwixt the ſolid Parts; 3. A Compreſſure of the Veſſels, ſo as to expel their contained Juices, and conjoin their Sides together.

§. 471.

§. 471. The great *Number* [1] therefore of the Veſſels which are almoſt infinite in the Fœtus or Embryo, is gradually decreaſed, in proportion as Age advances.

[1] This may perhaps ſeem a Parodox to ſome, notwithſtanding it is moſt certainly true. For in the adult Perſon there are no new Veſſels formed; and if we compare the Table of Arteries which *Cowper* has given us from a Fœtus with thoſe of an adult Body, we ſhall find the ſame in both, and that there has been no Addition of any new Artery made in the Adult. Thus there are two coronary Arteries in the Fœtus, and there are but two in the Adult, though they are larger in the latter; ſo are there two Carotids in the Fœtus, nor are there more in the Adult; and even the ſmaller Branches or Ramifications of the Arteries, which are viſible to the Eye in an Adult, may be alſo traced by the Microſcope in a Fœtus. But, on the other hand, we obſerve in the Adult, that five of the larger Trunks or Veſſels, which we mentioned at §. 468, are deſtroyed and cloſed up, whereas they remain open in the Fœtus. But the ſame thing is demonſtrated to take place throughout the whole Body. Thus in the Palm of the Hand of a young Girl, there are an infinite Number of exhaling Veſſels diſcharging a Vapour, which obſcures a Looking-glaſs or a Piece of poliſhed Gold, whenever they are touched by the Hand; but as the Country Girl grows up, and becomes inured to hard Labour, all thoſe minute Veſſels are deſtroyed and cloſed up into one continued Callus, which lines the internal Surface of the Hand; and in this manner the Blackſmiths of *Amſterdam* have their Hands lined with ſo thick a

Callus, that they can handle a red hot Iron without Pain. The *Roman* Cenſors were much in the right, when after examining the Hands of the Citizens, they depoſed thoſe as an effeminate Order of Men, whoſe Hands were found ſoft and ſmooth. Even the Wrinkles which appear in the Forehead of an old Perſon, demonſtrate the Deſtruction of an infinite Number of the cutaneous ſmall Veſſels and the cellular Fabric, which filled out the Skin. *Ruyſch* has demonſtrated, that when the Veſſels of a Fœtus are injected, an infinite Number of ſmaller Veſſels appear in the Coats of the Arteries, which cannot be demonſtrated in the Adult by any Injection, but are ſo entirely obliterated, that the Part of the Aorta which comes immediately from the Heart turns callous, and becomes at length cartilaginous, or even bony. All the Vertebræ of the Spine in a Fœtus are each of them compoſed of a Body and Appendices; but the Bodies of the Vertebræ cohere to their Appendices neither by Muſcles nor Ligaments, but merely by a peculiar Sort of Veſſels. But from one Vertebræ to another, there are Fibres which paſs in a perpendicular Courſe, and enter into the Subſtance of each Bone; but in old Age theſe flexible Fibres are all deſtroyed, and the Bodies of ſeveral Vertebræ concrete together into one Bone. The Skull of an Embryo is truly membranous, and compoſed of Veſſels; all which Veſſels are effaced, and turned into one ſolid continued Bone in old Age.

§. 472. For the ſame Reaſon alſo, on the other hand, Weakneſs goes off, and *Strength*[1] is increaſed in the ſeveral Parts of the Body, as the Age advances.

Concerning

[1] Concerning the Coheſion of the Fibres and their elementary Particles, we treated before (§. 467.) But when Fibres thus formed, are conjoined with others of the ſame Make into one ſolid Body, the Power of their Coheſion will then be immenſely greater. For if a Fibre is compoſed of ſix Sides which adhere to others, its Coheſion will be ſix times greater than before, and twelve times greater if it had twelve Sides. For *Euclid* has demonſtrated what Figure can fill up any whole Space, namely, a ſquare Hexagon, *&c.* But the Strength of the Fibres is eſtimated only from their Coheſions, ſince the intermediate Spaces do not make any Reſiſtance, and therefore cannot augment the Strength of a Fibre. The more numerous therefore the Fibres which cohere together, and the leſs the intervening Fluid which is interpoſed between them, ſo much more in proportion is the Strength of the Body increaſed.

§. 473. In Youth therefore the Quantity and Force of the Humours exceed beyond the Solids.

§. 474. But in *old People* [1] the Force and Quantity of the Solids prevail over the Fluids.

[1] So long as a Fluid is interpoſed betwixt the Sides of the ſolid Fibres and Veſſels, they do not cohere together. Thus two poliſhed Pieces of Marble do not cohere, unleſs their Surfaces are covered with Oil or Wax, ſo as to exclude the intervening Air, and then they will ſuſtain the Weight of ſix hundred Pounds without being pulled aſunder. But in old Age there are innumerable Veſſels obliterated and turned callous, which

in the time of Youth and in the Fœtus were pervious and open; and therefore the Force or Strength of the Solids is gradually increaſed, till at length they reſiſt any farther Dilatation. All the Increaſe therefore or Growth of the Body ſtops, ſo ſoon as the Force of the Heart can no longer extend the bony Fibres. The Head never increaſes after the Sutures are obliterated, and the Thigh-bone is no longer extended in Length, when the Force of the Heart is not ſufficient to remove the elementary Particles from their mutual Contacts. Even the Growth of the Muſcles themſelves terminates, when the Bones are no longer extended; for they cannot be elongated, unleſs the Bones are alſo lengthened at the ſame time.

§. 475. From hence we may underſtand the Manner, Cauſes, and different Appearances of the *Growth* [1], full Stature, and Decreaſe of the Body, with that *Death* [2] of the Body, which reſults merely from old Age, and its *Cauſe* [3].

[1] So long as the Force of the Heart is greater than the Reſiſtance of the Veſſels, ſo long are theſe latter extended, and the Body enlarges both in Length, Breadth, and Thickneſs; but when the Force or Reſiſtance of the Veſſels ariſing from the greater Firmneſs and Coheſion of the Fibres becomes more than equal to the dilating Power of the Heart, in that Caſe the ſolid Parts continually contract themſelves, and the whole Body declines or falls away.

[2] A healthy ſtrong Perſon who is arrived to the fiftieth Year of Age, begins then to decline from the full Habit of Body; the Eyes begin to flatten, and the Perſon becomes ſhort-ſighted, nor is a mo-

derate Quantity of Light ſufficient to render the Objects viſible; the Hearing becomes difficult alſo, and the other Senſes with the Faculties of the Mind become weak and dull. Some time after this the Body itſelf is inflected, the Head falls down betwixt the Shoulders, and the whole Body becomes at leaſt two Inches ſhorter; for the Spine itſelf is ſhortened by ſeveral of the Vertebræ conjoining into one Bone, when the intervening Cartilages or Ligaments are compreſſed and reduced into a thin bony Lamella continuous with the Bodies of the Vertebræ themſelves. By Degrees the Mind itſelf becomes feeble and childiſh, and at length that eaſy Extinction of Life which the Ancients ſo much wiſhed for, follows from mere old Age, without thoſe Agonies experienced by younger Perſons, who are killed by Diſeaſes before the Strength of the vital Organs has been exhauſted; inſomuch that Death following from mere old Age, may be rather termed a Ceſſation of Life than a Deſtruction of it by Diſeaſe, ſince the Arteries become ſo much indurated as perfectly to reſiſt the Blood impelled from the Heart. In ſhort, the ſmalleſt Veſſels both in the Brain and Organs of Senſation are by degrees cloſed up, and then Death itſelf is near at hand, namely, when the Cerebellum ſuffers the like Alteration. But the Veins only receive the leaſt Alteration as being almoſt deſtitute of the contractile Force, and hence the Veins of old People are large and flaccid.

3 Vain therefore are the Boaſtings of the Chemiſts, who promiſe that they can prolong Life by their Elixir: for they conceive Life to be as it were a Flame, and if it was really ſo, one might reaſonably expect ſome good Effect from Chemiſtry to anſwer that Purpoſe. Beſides this they confound different Operations together, and

imagine that to preſerve a living Body is the ſame as to preſerve a dead one, with Myrrh, Aloes, *&c.* If they were capable of continuing the vital Motions, we ſhould readily grant that the reſt might be very well expected from chemical Medicines; but, on the contrary, the Buſineſs is to open Veſſels which are concreted together and become callous, which is not within the Power of Chemiſtry to effect.

§. 476. Whoever conſiders this whole Hiſtory or Account of Nutrition, and then compares therewith thoſe Accidents which happen in the Body, he will clearly perceive all that we have here advanced to be truly the Caſe: for the whole Cuticle perpetually ſcales off throughout the whole Body, and is again *renewed* [3]; the *Hair* [2], *Nails* [3], and *Teeth* [4] being continually ſhaved, cut or abraded from their proper Places, grow again; the loſt Subſtance of the Veſſels, *Bones* [5], and other Parts, are ſoon renewed from every Point; alſo the *Sordes* [6] or Matter collected from the Extremities of the Veſſels throughout the whole Body either by ſcraping or condenſing, being diluted in Water, and examined by the Microſcope, appear to be compoſed both of the ſolid and fluid Parts of the Animal; and the ſame Matter obtained from the ſolid Parts either by waſhing, rubbing, or ſcraping, has the ſame Appearance as before.

[1] This is demonſtrable various Ways. For the Callus is not merely the Cuticle thicker than uſual, but an Aſſemblage of exhaling Veſſels compreſſed

preſſed and indurated into a denſe and horn-like Subſtance, which is neither perſpirable nor tubular, but conſiſting of Scales, an infinite Number of which are concreted into one Membrane. If a Smith, who has ſuch a Callus in his Hand, ſo mollifies the ſame by Maceration, that it all ſeparates from his Hand even to the ſoft Skin or Fleſh, he will not by that Means recover a ſoft Hand, unleſs he abſtains from his uſual Labour: for if he returns again to work, another Callus will be formed, and his Hand will recover its former Hardneſs. The ſame thing is alſo demonſtrated by abrading or removing thoſe Spots, which being burned in the Cuticle are indelible by any Artifice whatever. If you diſſolve Gold in Aqua regia, and touch any Part of the Body with the Solution, it ſtains a beautiful purple Spot in the Cuticle not to be removed by any Artifice; but in a few Days after, the Cuticle itſelf ſcales off, and a new Skin appears without any ſuch Spot. Therefore the Extremities of the Veſſels are continually protruded from within outwards all over the Body, and when abraded or deſtroyed, they are afterwards renewed again. But if the Cuticle is ſo eaſily renewed and altered, it may be aſked, Why the ſame thing does not happen to the Pleura and other Membranes, which are all perforated likewiſe with the exhaling Veſſels? To which we anſwer, That the Epithelia or internal Cuticle, which lines the alimentary Paſſages and other Parts, has certainly ſmall Veſſels, and is likewiſe abraded and renewed; but then the Particles caſt off are too ſmall to come under the Obſervation of our Senſes.

[2] If all the Hair of the Body was to be ſhaved off cloſe to the Skin, it would grow again to its former Length within the Space of ſix, ſeven, or eight Months. When an *European* Perſon goes

into *Aſia*, where he is obliged to follow the *Eaſtern* Cuſtoms, by which it is a ſcandalous Sight for a Man to appear without his Beard, upon ſuffering it to grow, it acquires its full Length within the Time before-mentioned, beyond which it will grow no more. But in us who ſhave every two or three Days, there is certainly as much or a greater Length of Hair taken off within that Space of Time. If People who wear their own Hair would ſave and weigh that which is combed off, they would find it to be equal, in a Year's Time, to that of the whole Head; and therefore the whole Head of Hair is renewed once in ſix Months. I examined the Hair which was of a different Colour from the reſt, and perceived that its Colour proceeded gradually from the Apex or Extremity towards the Middle, while its natural Colour was continued to the Root from thence. Our Hairs are therefore changed and extirpated in the ſame manner as other Plants, though perhaps ſomewhat more ſlowly; for in thoſe Vegetables which are called Ever-greens, there are Branches and Leaves caſt off, as we ſee in the Juniper, Ivy, *&c.* only they differ in this from the Generality of Trees or Shrubs, that they do not caſt off all their Leaves at once, but by a few at a time, while others ſucceed by degrees to ſupply the Place of thoſe which are caſt off. Hence therefore we may ſee that the Hairs cannot grow in a dead Body; which was a popular Error until it was refuted by *Ruyſch*, who by examining the Bodies of many Women after they had been buried thirty Years in their Tombs, could yet never obſerve that the Hair was grown in the leaſt longer. For the Hairs are Continuations of the cutaneous Veſſels themſelves; nor can they be elongated or extended, but by the vital Powers which protrude the Parts from within outwards.

[3] I made a ſmall purple Spot with a Solution of Gold in Aqua regia, upon the Lunula of the Nail of my Finger, and obſerved that it by degrees moved towards the Extremity, ſo that by the third Month it was advanced far enough to be cut off. If a Perſon neglects to cut his Nails for a conſiderable Time, they become ſtrong and crooked, equal to the Length of the laſt Joints of the Fingers, as we ſee in Brutes. Concerning the Reproduction of Horns we treated at §. 459; and indeed it is ſurpriſing that a Stag, who has been caſtrated, ſhould not in the ſame manner caſt his Horns; which is a ſtrong Argument that ſomething returns again from the Semen into the Blood capable of thruſting out or elongating the Fibres and Veſſels, ſo as to cauſe the Horns to fall off, and grow up again.

[4] There was a certain modern Anatomiſt who denied that the Teeth received any Growth or Nutrition; whereas it is certain that when any of the upper or lower Teeth have been extracted, thoſe which remain oppoſite to the Vacancy grow out beyond the reſt of the Teeth in a ſurpriſing Manner, becauſe it does not continue to be wore away by grinding upon the other Teeth. It is therefore certain that every one even of the hardeſt Parts of the Body are furniſhed with very ſmall Arteries not excepting the Teeth themſelves, by which Veſſels the nutritious Matter is continually ſupplied, and the Parts elongated, though by a gentle, yet by a continual Force.

[5] If any Bone which is of a conſiderable Length, and hollow on the Inſide, be fractured in ſuch a Manner that ſome Part of it falls out and leaves a void Space, (as I once obſerved no leſs than for the Space of two Inches in a young Man who broke the Tibia of his Leg) in that Caſe a mucilaginous or

gelatinous Subſtance ſprings from every Point of the broken Ends of the Bone, which if ſcraped off prevents the Regeneration of the Callus. But if that Subſtance be left upon the Bone, and defended from the Air with Powder of Myrrh, Gum Sarcocol, or the like, that Mucilage is then condenſed into a Membrane, which by degrees becomes a Callus as tough as Leather, and afterwards hard and more compact than the Bone itſelf. If therefore the elementary and nutritious Particles are thus ſent in all Directions from within outwards by the proper Veſſels, even in Parts ſo compact and rigid as the Bones themſelves after Fractures, it is therefore evident that the ſame Matter is continually propelled the ſame Ways in the healthy Body; and if the Bones thus continually grow and are ſupplied with nutritious Matter, how much more readily may we conceive all the other Parts to be nouriſhed and increaſed in the ſame Manner?

[6] If the Hands are waſhed very clean, and then rubbed pretty hard upon one another, there will appear innumerable conical or ſharp-pointed Particles or Scales like Threads, which Children uſually call Worms. If again theſe Scales are diſſolved in Water, they depoſit an oily Liniment, and leave nothing but the mere Scales alone, namely, the Productions or Extremities of the ſmall exhaling Veſſels. You will alſo perceive very large white Scales of this Nature, if after waſhing the Hands clean with Soap and rubbing them, you put on Gloves lined with black Velvet, and wear them next to the Skin for eight or ten Days: and this is an Experiment of *Lewenhoec*, a Man of infinite Patience and Induſtry, to whoſe Writings we are much indebted. The Scurf or Scales which are continually ſcraped off in combing the Head, are nothing

more than little Particles of the Cuticle abraded or caſt off; inſomuch that I can readily believe, that as Serpents caſt their Skin yearly, and as Silk-worms depoſit the ſame four times in a Year, ſo the human Species depoſit or caſt off their Cuticle every Month.

§. 477. From hence we may likewiſe underſtand, that the Increaſe of Bulk in the Body, with reſpect to the whole Habit, in large, fleſhy, and *fat* [1] People, does not proceed from an Increaſe of the Solids, but only from their having larger Cavities filled with ſtagnating and accumulated Humours, by which they are extended; for which reaſon Fatneſs is troubleſome, weakens and infringes the Circulation. Hence therefore the Phyſician ought carefully to diſtinguiſh betwixt Repletion and Nutrition, ſince the one ſtrengthens and thickens the Veſſels, while the other weakens, relaxes, and extends them.

[1] The ſame Perſon may ſo increaſe in Bulk, that his Body ſhall exceed twice its former Weight, without the leaſt Addition made to any of the ſolid Parts, as we ſee in the Leucophlegmatia or Dropſy of the Veins, and in Obeſity. A Man who has undergone a mercurial Salivation, ſo as to evacuate almoſt his whole Body, after he is recovered and ſupplied with good Aliments, eaſily gains his former Bulk. And by Exerciſe or Labour his Body may be reduced again to a State of Leanneſs. But yet in none of theſe Caſes are the Muſcles themſelves enlarged. The Heart of the Plowing-Ox is light, and compoſed almoſt entire-

ly of muſcular Fibres; but if the ſame Animal is put to fatten, the Heart will weigh three times as much, being buried in Fat; and if the ſame Heart be boiled in Water for a conſiderable time, the Heart will be found nothing larger than at firſt it was in its lean State, becauſe the Fat is melted down and diſcharged. A lean Hog, whoſe Muſcles lie ſo cloſe to the Skin, that they are eaſily wounded by a ſlight Puncture through that Integument, does yet arrive to ſo great a Degree of Fatneſs by ſix Months Feeding, as to be three, four, five, or even ſix times his former Weight, when at the ſame time his Muſcles and Veſſels are rather leſs than before; but the Bulk ariſes entirely from the Lard interpoſed betwixt the Muſcles and the Skin. But although the Animal is thus increaſed in Bulk, yet neither are the Veſſels increaſed in Number, nor the Bones in Length; nor are the Nerves, Cartilages, or any other ſolid Parts enlarged or augmented one Grain in Weight; nor is the whole Maſs of Blood augmented in the leaſt: but, on the contrary, the ſanguiferous Veſſels are rather compreſſed and diminiſhed, and the Maſs of Blood itſelf leſſened in proportion as the Fat is augmented. Thus in a lean Perſon, where it is eaſy to open the median Vein, if the ſame Perſon grows Fat, that Vein can be ſcarce found or perceived, not from changing its Situation but from being compreſſed or diminiſhed. In Oxen and in Hogs which have fattened to the laſt Degree, there is very little Blood. Phyſicians ought therefore to be mindful that lean People eaſily ſupport Bleeding, but that Phlebotomy in fat People is generally prejudicial.

In lean People there is Abundance of Juices, and the ſanguiferous Veſſels or thoſe of the firſt Order are very large; but in fat People a great

Part of the Blood being turned into Oil, ſuppoſes a Diminution of the ſanguiferous Veſſels and their Juices. Hence Fatneſs obtunds all the Faculties, renders the Perſon unfit for Action, and haſtens the Period of Life. But in order to preſerve Health entire, the Body is to be exerciſed with frequent Labour that it may never be oppreſſed with Fat. Lean Animals which are generally imagined to be weak, are nevertheleſs the ſtrongeſt and moſt active.

§. 478. From hence alſo the Reaſon is evident, why the Fabric of our ſolid Parts is not *diſſolved* [1] by their contained Juices? as alſo from whence it happens that our Machines are capable of ſubſiſting ſo long in a Capacity for *Motion* [2]? whence it is that the *Nerves* [3] being any way deſtroyed, the Nutrition of the Part to which they belong is then aboliſhed? and alſo why the Nouriſhment of the Part is likewiſe aboliſhed when an *Artery* [4] is deſtroyed? why in an *Embryo* [5] there are no ſolid Parts, very few in a Fœtus, and why they abound moſt in very old Age; inſomuch that in the laſt, the Nerves, Tendon, *Arteries* [6], and other Receptacles become cartilaginous and then bony.

[1] The ſolid Parts of our Bodies are compoſed of mere Earth, which is ſo cloſely connected by the Intervention of Water and Oil without any alcaline Salt, that only Fire or a long continued Putrefaction can ſeparate its Parts from each other. From hence we may eaſily underſtand why the Motion and Flux of our Juices does not diſſolve and waſte the ſolid Parts of our Bodies. Nor ought the

Strength of Coheſion in the Solids to ſeem new or incredible, ſince from Water and Earth ariſe ſolid Bodies, which cannot be again diſſolved by Water. Clay that is well dried turns into a volatile Duſt which offend the Eyes of the Traveller; but the ſame Clay being mixed up with Water, formed into Balls and ſlowly dried, does at length turn into a hard Stone, by paſſing gradually through the ſeveral Degrees of Fire; after which it is no longer capable of being diſſolved in Water, notwithſtanding that was the Medium by which the Particles were gradually brought into more cloſe Contact, ſo at length to aſſume the Hardneſs of a Stone: for when the Water is expelled both in the Cricks and in the ſolid Parts of Animals, they both of them are then a mere ſolid Earth.

[2] We very often ſee Men of ninety Years old capable of ſuſtaining all the Functions of Life, which would almoſt ſeem incredible to a Perſon who conſiders what violent and perpetual Motions our ſoft and tender Machines ſuſtain during the Space of ſo many Years. I know that this is nothing new nor ſurpriſing with the Generality of Men; but when the Philoſopher of old was aſked, What was the moſt wonderful? he wiſely anſwered, That which the Vulgar did not admire; for we are ſurpriſed at unuſual things, while we neglect thoſe as inſignificant which occur to our daily Obſervation, notwithſtanding they deſerve more of our Attention and Admiration, in proportion as they are perpetual Benefits which we enjoy. This Activity therefore in ſome very old Men is the Conſequence of their Veſſels remaining pervious or moveable, but this is effected by the Intervention of Water or Moiſture, which is transfuſed betwixt the Fibres; to which add the Oil abounding in our Aliments, and ſwimming in large Quantities under the Form

of Cream, lubricating and mollifying the ſolid Fibres and Veſſels, ſo as to facilitate their Motions. But when theſe ſmalleſt Veſſels concrete together by the Actions of Life, the oily and watery Juices are expreſſed from betwixt the Fibres, and being conſumed, they cauſe that kind of Death which follows from mere old Age, namely, from the too great Reſiſtance of the ſolid Fibres and Veſſels overpowering the Force of the Heart. If a Perſon could prevent the ſmalleſt Veſſels from concreting into Fibres, he might render Life perpetual; but this is what no Mortal can effect. It is an Axiom which we in general experience to be true, as well in Animals as in Vegetables, that thoſe which arrive ſooneſt to their full Growth, ſurvive the ſhorteſt time; whereas, on the contrary, thoſe Animals or Perſons who are a long time in growing, theſe continue a long time in the ſame State, and are alſo a long time in decaying. Even theſe three Stages of Growth, Duration, and Decay, generally take up an equal Number of Years. Thoſe Animals which grow for the Space of twenty Years, continue in their full Strength until the Age of forty, from which time their Forces decline, and hardly continue beyond the ſixtieth Year. The great Climacteric Year, namely, the ſixty-third, is compoſed of the three Stages of Life before-mentioned, containing each twenty-one Years. Thoſe who are addicted to hard Labour in their younger Years do not live ſo long as they otherwiſe perhaps might.

[3] It is found by Experience, that after a Nerve has been tied in a living Dog or deſtroyed in the human Body by ſome Diſeaſe, an Inſenſibility and Waſting follows in thoſe Parts to which that Nerve was diſtributed; namely, becauſe Nutrition is carried on in the ſmalleſt Veſſels, which as far as we

can perceive muſt be the Nerves themſelves, whoſe Trunks being compreſſed, their Branches will collapſe. But this kind of Waſting is called a Withering in the Parts.

[4] From the Arteries ariſe ſmall Veſſels, no larger than the nervous Threads themſelves, which ſmalleſt Arteries are deſtined to the like Office of immediately carrying on the Buſineſs of Nutrition. We know not of any Reaſon why the Artery ſhould not divide into Branches equally minute in the other Parts of the Body as in the Brain itſelf; but yet ſuch ſmall Arteries muſt be deſtitute both of the Power of producing Motion and Senſation, ſince both theſe Faculties reſult only from the Encephalon. But Nutrition is principally carried on in theſe ſmalleſt Arteries, which convey Juices next in Subtlety to the Juice of the Nerves themſelves.

[5] The Fœtus, which does not exceed the Size of an Ant, is nevertheleſs viſibly compoſed of a Head, Brain, Eyes, and protuberant Limbs; and has doubtleſs alſo the Veſſels of the Brain, the Veſſels of the Skull, and all the more ſubtle Parts, without which thoſe larger viſible Parts could not be produced; yet the whole is no more conſiſtent than a Mucus, and diſſolves like a Fluid with the leaſt Touch, much leſs is there the Appearance of Bones. But we are uſed to diſtinguiſh Solids from Fluids only by our Senſes, and the Smallneſs of the Force which is required to ſeparate their elementary or conſtituent Particles. In Water that has had a Grain of Pepper infuſed into it for ſome time, no one would imagine or ſuſpect that it contained any thing ſolid, when at the ſame time it is every where filled with ſmall Fiſh: and even the ſharpeſt Vinegar viewed by the Microſcope in the Summer-time, appears full of white ſmall Eels friſking

about, which a Man of a ſharp Sight may even perceive with his naked Eye without the Help of a magnifying Lens. We ought not therefore to conclude, that thoſe are wanting in the Fœtus which our Senſes diſcover in the Adult, but not in the Fœtus, in which they retain the Conſiſtence of a Mucus. But in that State of the Animal the Solids bear the leaſt Proportion of all, being perhaps a tenth Part of the Animalcule which weighs a Grain; and from that Time the Proportion of the Solids to the Fluids continually increaſes, ſince ſome Parts of the latter are perpetually converted into a ſolid Nature. In a Collection of Fœtus's which I poſſeſs, the Skull in the firſt Month is a mere membranous Bag; but in the ninth Month it is partly membranous, and partly of a bony Nature. And even for ſome time after the Birth, a great Part of the Bones is mere Cartilage, and pervaded with almoſt an infinite Number of ſmall Veſſels. But the ſame Bone in Proceſs of Time is ſo compreſſed by the Pulſations of the Arteries in the Perioſteum with the Preſſure of the adjacent Muſcles, that they are at length condenſed and compacted into Bones of the greateſt Hardneſs. After this the Ligaments alſo by degrees become tough and inflexible as Cartilages, and the Cartilages themſelves interpoſed betwixt the Vertebræ turn into Bones. I have ſeen all the Ligaments of the Vertebræ, Neck, Back, and Loins, with the Os ſacrum concreted into one continued Pillar of Bone, and the Tendons themſelves changed into bony Skewers; the Septum and Cavities of the Heart with the falciform Sinus and other Membranes were oſſified, namely, by expreſſing the Fluids which interpoſe betwixt the ſolid elementary Particles. But the Origin of Solidity in the Bones generally proceeds from a Point or Center, and extends itſelf towards the Circumference, as we may plainly perceive in the Bones of the Forehead; but by degrees the Veſſels are enlarged, and the ſmalleſt of them compreſſed ſo that they concrete by their Emptineſs.

[6] We have a notable Inſtance of this Truth in the Bone of the Stag's Heart, or the Oſſification formed in the Beginning of the Aorta, which is continually found in this long-lived, active, and ſwift-footed Animal, when killed after long chaſing. Some Phyſicians have ſearched for this Bone in thoſe Stags which Princes breed in their Parks, without being ſo ſucceſsful as to find it; for it is only to be met with in thoſe which are old, and have been frequently hunted; and in theſe it is generally formed by the Palpitation of the Heart which precedes Death. The *Arabian* Phyſicians ridiculouſly attributed high Virtues to this Bone, ſuppoſing it to be capable of rendering a Perſon equally active and long-lived with the Animal from whence it is taken; which is much the ſame as to recommend the Feet of a Hare to a Perſon whoſe Buſineſs it is to run. In ſhort, ſuch bony Calloſities and bony Productions ariſe in all Parts of the Body; and the Feet of Letter-Carriers are armed with a kind of Soles of the Conſiſtence of Horn.

§. 479. From hence likewiſe we may underſtand the *Number* [1] and Variety of Orders there are in the Circulation of our Juices, with the Proportion and Difference of the *Effects* [2] which from thence follow? as alſo how we may ſolve the *Problem* [3] concerning the Time in which all the Humours may paſs in one Courſe through the Heart? with other

Queſtions of the like Nature, which to a haſty and inconſiderate Perſon may appear eaſy, but will be found very difficult, or altogether impoſſible to be reſolved by a Perſon who thoughtfully makes the Attempt.

[1] Altogether as many as there are different Parts in the Body; for every Part has its peculiar Circulation, as is evident from the particular Fabric of each; nor can the Nature of each Circulation be underſtood, unleſs we have a thorough Knowledge of the minute Structure of each Part. For the Velocity of the circulating Humours varies in Proportion to the Diſtance of the Part from the Heart, according to the Elaſticity of the Veſſels, their Angles or Incurvations, *&c.* In general, the Circulation is the ſwifteſt when the Blood paſſes thro' the Heart to and from the ſanguiferous Veſſels of its muſcular Fabric, which may be performed within $\frac{1}{3600}$ Part of an Hour (§. 187): for in ſo ſhort a time does the Heart look red, and again become pale, from its being filled with and emptied of its Blood; and in ſo ſhort a Space of time at leaſt is there an Ounce of Blood tranſmitted through the ſmalleſt Veſſels of the Heart. But that this is the Capacity of the vaſcular Syſtem in the Heart is demonſtrated by injecting Water ſo as to fill the cardiac Arteries, and after expreſſing the ſame, comparing the Weight of the Heart with what is weighed before, the Difference of which will be equal to an Ounce. From this great Velocity it is that the Blood of the Heart is extremely thin, and inclined to Putrefaction. But the Circulation is ſlower in the other Parts, in proportion as they are more remote from the Heart. Next to the Heart the Circulation is quickeſt in the Pericardium, which is perpetually agitated by the Heart itſelf,

and Motion of the Diaphragm. We read in the Works of *Peyerus*, that if the Pericardium is wiped dry in the living Animal, there would be a continual Succeſſion of Drops of the Humour which it ſeparates from the Blood. In the Lungs the Circulation is finiſhed within the third Part of a Minute, or ſomething leſs (§. 208); for we count almoſt ten Pulſes to one Reſpiration. After the Lungs the Velocity of the Circulation is greateſt in the bronchial Veſſels, next in the Intercoſtals, and then in the Brain. In general, the Circulation is quickeſt in the vital Organs, but ſomething different in each; whereas in all other Parts of the Body it moves ſlower according to particular Circumſtances. Hence a Dropſy firſt ſhews itſelf in the Feet and Legs, *&c.* Among the Viſcera the Blood moves ſloweſt through the Liver (§. 337, 350), but the ſloweſt of all in the Body through the Bones, in which it is probable that the Circulation hardly compleats its Courſe within a Month.

[2] Namely, both to deſtroy and to nouriſh the Parts; and therefore the Heart, in which the Circulation is the moſt rapid, is of all Parts the ſooneſt deſtroyed, and the ſooneſt repaired.

[3] Firſt, *Harvey*, and afterwards *De Back* and *Wallis* attempted to determine the Space of Time in which all the Humours of an animal Body might paſs through the Heart. Their Calculations were raiſed without much Difficulty. Suppoſe, for Inſtance, there are two Ounces of Blood expelled at each Contraction of the Heart, ſince it appears that each of its Ventricles is capable of receiving ſuch a Quantity, and evacuating themſelves entirely at each Syſtole; and ſuppoſe again the Pulſation of the Arteries to be 3600 times in an Hour, and that the Quantity of Blood in a healthy Man is ſixteen Pounds; it will from thence eaſily

appear, that theſe ſixteen Pounds of Blood muſt have paſſed twenty-eight times through the Heart within the Space of an Hour. But this was not the Queſtion; for in this Manner is determined the Quantity of Blood paſſing through the Heart in the Space of an Hour, but does not aſcertain the Time in which the whole Maſs of Blood in the Body may paſs through the Heart, excepting what exhales; nor does it determine the Time in which the ſame individual Ounce of Blood will again return to the Heart from whence it paſſed; nor does it inform us of the Time in which any Part of the Maſs of Blood circulates through any particular Membrane or Viſcus, or what the particular Velocity of the Blood is in each Veſſel; for theſe are Queſtions to which no one will anſwer, unleſs he is perfectly acquainted with the Fabric of each Viſcus, and the Power of every individual Veſſel. But theſe Particulars I am afraid will never be exactly known: for Example, to determine the Time in which a Portion of Blood paſſes through a Finger, we ought to be acquainted with the Reſiſtance which the Artery makes to the Heart, with its Area or Diameter, *&c.* But ſuppoſe every neceſſary Circumſtance to be determined in a Man who is ſleeping, if he does but awake and move his Finger, more Blood will paſs through than before, and ſtill more if he increaſes the Motion of it. The Circulation of the Blood is therefore in ſome Parts very quick, and in others very ſlow; and therefore an Ounce of Blood paſſes frequently through the Heart, before another Ounce returns once from the Heart to the Extremities.

§. 480. The Order or Method of Science next requires us to treat firſt of *Sleep* [1] and Vigilance;

gilance; but as in theſe we always meet with Reſt or Exerciſe of the external and internal Senſes, with what relates to them, therefore we are naturally led by the Courſe of things to enquire into the external Senſes; and in the firſt place we are to treat of the moſt ſimple, common, and general Senſe, which we call the Touch or Feeling.

[1] Half the Life of Man is ſpent in Sleep; and during that Space he is not Man, but a mere Automaton. During the other Part of Life which is ſpent in Vigilance, thoſe Motions which are carried on merely as in a Machine in the time of Sleep, are not ſo well performed, notwithſtanding he is conſcious of them. But in a ſound Sleep, every Part which is governed by the Influence of the Mind, together with the Will, Memory, Reaſon and Imagination itſelf ceaſe; for thoſe who contend that theſe Actions take place in Sleep, ſuch confound dreaming with Sleep, namely, a Mixture of Vigilance with Sleep (§. 590, and 599). But there is another Difference which comes betwixt Sleeping and Vigilance, and this is a ſort of Medium betwixt both: namely, in Sleep the Motion of the Heart remains, while the Reſpiration, Digeſtion of the Aliments, with the Secretion, Perſpiration, and Heat of the Humours go on; only the Senſes are at Reſt, namely, the Sight, Touch, Hearing, and voluntary Motions. Since therefore Sleep is defined to be a Privation of theſe Senſes, we ought firſt to conſider them, in order to obtain firſt a perfect Knowledge of Sleep. But, among all the Senſes, the Touch is the moſt ample, all the reſt being only certain Species of feeling

ing or touching Objects mediately or immediately. Thus to hear, is to perceive the Vibration or Percuſſion of the external Air, drove in a tremulous Motion through the Feneſtra ovalis; to ſmell, is to perceive the Changes or Impreſſions made by odoriferous Particles themſelves upon the Papilla of the olfactory Nerves: but the Touch or Feeling is the Perception of the Changes made throughout the whole Surface of the Body by the Application of any Object; and therefore that moſt ample and obvious of the Senſes which we call the Touch, ought to be firſt conſidered.

FINIS.

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